

NEW MILLENNIUM PROGRAM EARTH ORBITER-1 PROJECT

**Mission Operations Plan
for the
New Millennium Program
Earth Orbiter-1
(NMP/EO-1) Mission
Draft Version**

April, 1997



National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Mission Operations Plan

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Preface

As a space flight mission, the NMP EO-1 Project (Code 426) is responsible for the operation of the NMP EO-1 satellite and the ground systems and activities that support it. This document, the Mission Operations Plan (MOP), demonstrates that the NMP EO-1 Ground System design is operationally feasible and will, when placed in its various operating facilities, perform all its mission-critical functions.

The MOP provides an overview of the entire EO-1 system and describes how it will be operated.

Acknowledgment

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Section 1. Introduction

1.1 Authority

This Mission Operations Plan (MOP) responds to direction from the NMP EO-1 project manager to provide an operational plan for the entire NMP EO-1 ground system. This document will be available for review in the context of the ground system Confirmation Review.

The NMP EO-1 project is funded by the National Aeronautics and Space Administration (NASA). The NMP EO-1 Project Office (Code 426) is administered under the New Millennium Program, NASA Headquarters, and has overall responsibility for the project's development activities. The NMP EO-1 Project Office is located at Goddard Space Flight Center (GSFC), Code 426, and the ground system is being developed by GSFC.

1.2 Document Purpose and Scope

The purpose of the EO-1 Mission Operations Plan is to serve as a baseline reflecting how the space and ground segments operate and interact to achieve the mission objectives. The MOP serves as an overview to the operations within the EO-1 system. Specific documents will be created that will describe operations within the individual elements and these are referenced within the text. System overviews and descriptions are provided where appropriate. The major emphasis of the EO-1 MOP is the On-Orbit Mission Operations phase as the pre-launch testing phase and launch and early orbit phase will be covered by separate documents (the GSI&T Plan, released March 19, 1997, and the L&EO Operations Plan, to be released).

1.3 Document Organization

The EO-1 MOP is comprised of 6 sections. A brief description of each follows:

Section 1: Provides a brief introduction to the document and the EO-1 mission.

Section 2: This section is a chart of document references.

Section 3: This section describes the flight system. It discusses the launch and space segments and the ground system.

Section 4: This is where normal mission operations are discussed. This section contains a mission operations description, information on spacecraft operations, real time operations, off-line operations, operational timelines, and mission management.

Section 5: Section 5 is concerned with special operations. It covers pre-launch, launch, and contingency operations.

Section 6: This section focuses on instrument operations. It covers data collection, data processing, planning, and data distribution.

Appendices: There are two appendices. Appendix A is a chart that shows the interfaces within the EO-1 system. Appendix B is an acronym list.

1.4 Objectives

1.4.1 Project Objectives and Goals

One of the key charges to NASA's Mission to Planet Earth is to ensure the continuity of future Landsat data. NMP's first Earth orbiting flight will validate technologies contributing to the reduction in cost of Landsat follow-on missions. The centerpiece is an advanced land imager (ALI) instrument. Once on orbit, EO-1 will provide 100-200 paired scene comparisons between the ALI and the Landsat 7 imager, ETM+. Such a comparison will validate the suitability of the multispectral capability of the ALI.

The EO-1 imaging system will also incorporate alternative and innovative approaches to future land imaging, including two different hyperspectral imaging techniques. One of these is a hyperspectral wedge spectrometer and the other is a miniature hyperspectral grating spectrometer. The two spectrometers view the same ground track through the same optics. This arrangement is designed to provide a comprehensive validation of the hyperspectral wedge technique. The miniature silicon carbide grating instrument also incorporates a novel compact optical design that integrates the visible and infrared focal planes. The two hyperspectral instruments will assess the acceptability of synthesizing Landsat bands from hyperspectral imaging data. One of the key parameters affecting the cost of future Landsat missions is the mass of the instrument. A smaller instrument translates into a smaller spacecraft, and a concomitantly smaller, less costly launch vehicle. The ALI represents approximately a seven-fold reduction in mass, power, and volume relative to its predecessor.

There is also a low-resolution hyperspectral wedge imaging system associated with the ALI. This device is a separate instrument designed to provide simultaneous atmospheric correction to the imaging data collected by the ALI. The Atmospheric Corrector is a small device with a simple interface which can provide "bolt-on" atmospheric correction to a variety of imaging instruments.

A number of other spacecraft technologies will be validated on EO-1, and are detailed in the Mission Description.

The NMP EO-1 Project Office is responsible for development of the NMP EO-1 system through development and acquisition of individual flight and ground segments. Code 426 will manage the acquisition of the satellite segment, as well as coordination of Flight System and Ground System development, testing, and initial operations with the launch segment at Vandenberg Air Force Base, California. The NMP EO-1 satellite is planned to have a minimum operational life of 1 year.

1.4.2 Ground System Objectives

The NMP EO-1 Project is responsible for the definition, development and acquisition of several individual elements of the NMP EO-1 Ground System. The NMP EO-1 Project is also responsible for coordinating support of other elements composed of the institutional systems required for mission operational support. These components are listed in Section 1.3 and are more fully described in Section 3.2. They will provide the necessary computing systems, hardware, software, facilities, equipment, and personnel to accomplish the following functions:

- Operational control and command management.
- Data capture.
- Level-zero data processing.
- Flight dynamics (orbit and attitude) determination and control, including end to end on orbit calibration of the attitude control subsystem and instrument.
- Coordination and scheduling the supporting ground stations and NASA Communications (Nascom).
- Ground system test and simulation.
- Assessment of quality of image samples, and generation of radiometric, atmospheric, and geometric calibrated data products.
- Coordination of NMP EO-1 science data processing and distribution with the Earth Observing System Data and Information System (EOSDIS) Land Processes Distributed Active Archive Center (LP DAAC) at Sioux Falls, South Dakota.

1.5 Background and Technical Summary

1.5.1 The NMP EO-1 Program

NASA is responsible for the implementation of the entire NMP EO-1 system throughout its life cycle. Interagency support will be provided through the Department of the Interior and the U.S. Geological Survey (USGS), which will operate the data handling system at the Earth Resources Observation System (EROS) Data Center (EDC) for data archiving and product distribution. The NMP EO-1 Science Working Group (SWG), located within the NMP EO-1 Program Office, will establish collection and production rules and priorities for NMP EO-1 operations.

1.5.2 NMP EO-1 Mission Description

The orbit of the NMP/EO-1 mission is associated with that of Landsat 7. The Landsat 7 orbit has an altitude of 705 km at an inclination of 98.2 degrees. It is sun-synchronous with a nominal equatorial crossing of 10 AM. The NMP/EO-1 spacecraft will fly in a sun-synchronous orbit at the same altitude but slightly offset from that of Landsat 7 such that the NMP/EO-1 spacecraft will fly over the same ground track as Landsat 7 but slightly behind it.

The preliminary mass estimate for the EO-1 satellite is 465 kg which includes some contingency. The EO-1 spacecraft is co-manifested with a second payload (SAC-C) being developed in

Argentina. The launch vehicle is a Delta 7320 (XL-38) and, for planning purposes, the launch will occur in May 1999.

The duration of the primary mission is twelve months which includes sufficient time to complete the technology and science validations described below. Beyond this period, the mission would enter extended operations if funding were available and the spacecraft and instrument were still operational.

1.5.3 NMP Technologies

Figure 1.1 reflects the NMP technologies already selected for EO-1. The complete flight validation of these selected technologies is the primary EO-1 flight objective, and the validation is to be completed during the first year on orbit.

There are three NMP categories for new technologies:

- **Category 1:** Defines the mission. Gives a reason for flying the satellite. The instrument optics and structure are a good example of this Category of technology because the mission is designed, at least in part, around these optics.
- **Category 2:** Replaces an existing system or device on the satellite that performs a critical function. For example, since the FODB replaces a more conventional high-rate data bus, the FODB is considered a Category 2 technology.
- **Category 3:** Receives a flight demonstration without interfering with higher-category technologies. Category 3 technologies can be secondary payloads such as the Copper Iridium Diselenide lightweight solar array demonstration, which operates and is tested without connection to the spacecraft power system; or they can be devices that are functionally switched in to the spacecraft when they are tested. The pulsed plasma thrusters are an example of this type.

Technology	NMP Cat.	Description
SiC optics and structure	1	The optics and their structural support are made of SiC, a high thermal conductivity, low CTE material that creates an a-thermal instrument.
Wide FOV, high-resolution, reflective optics	1	Telecentric optics are compact, high-resolution, and contain no moving parts; ideal for push-broom instrumentation.
Hyperspectral wedge filter	1	Compact, low cost, low mass detectors provide spatial and spectral resolution on a single detector.
Non-cryogenic detectors	1	Detectors at approximately 220 K use TEC and passive radiators rather than cryogens.
Calibration methodologies	1	Use the sun and moon to demonstrate techniques to get 5% absolute and 2% pixel-to-pixel relative radiometric calibration.
Miniature, hyperspectral, grating spectrometer	3	Using small grating to disperse the images and measure entire VNIR/SWIR spectrum at once. Receives images from a slit in focal plane.
Atmospheric corrector instrument	3	Measures water vapor and aerosols to correct ground images for absorbance by the atmosphere.
Pulsed plasma thrusters as attitude-control actuators	3	Low cost, low mass, easy-handling, high I_{sp} propulsion system demonstrates use for attitude control. ACS commands will go to PPTs instead of pitch wheel to demonstrate feasibility of closed loop control.
Solar array test panel	3	Small secondary payload to test CIS solar cells and ultra-thin mylar substrate.
Formation flying	3	Maintain orbit with high precision relative to another satellite. Ideally, performed autonomously without ground support. Enables coordinated, stereo, and near-simultaneous imaging.
Fiber optic data bus	2	Up to 1 Gbps data bus for high-rate science data. Will replace TAXI interface.
X-band phased array antenna	2	Use electronic pointing to achieve high gain without gimbals. Replaces earth-coverage antenna.
Carbon-carbon thermal radiators	2	Uses high-conductance composite materials as structural elements (composite facesheets) or radiators.

Figure 1-1. New Millennium Technologies on EO-1

Section 2. Document References

There are many documents that have been or will be written that deal with the operations of the EO-1 System. The EO-1 MOP has been developed using a combination of mission, spacecraft, science, and ground system documentation, in addition to interviews with subsystem and instrument engineers, science representatives, and system developers. The documents listed in the following table were used to build the EO-1 MOP.

SAI #	ALT. #	DOC. TITLE	STATUS	PRELIM DUE DATE	FINAL DUE DATE	RESP. ORG.	RESP. PERSON
MISSION LEVEL DOCUMENTS							
	EO1-MIS-XXX	EO-1 Mission Requirements Matrix	Prelim	11/8/96	2/7/97	GSFC	Stabnow
		L/V Documentation				GSFC	Vernier
		Design Reference Mission		11/8/96	2/7/97	GSFC	Stabnow
	NMP/EO1-MOP01	Operations Concept	Issue 1	10/31/96	1/13/97	GSFC	Muhonen
	NMP/EO1-MRR01	Mission Requirements Request	Draft	10/31/96	1/13/97	GSFC	Muhonen
	NMP/EO1-DMR01	Detailed Mission Requirements		2/10/97	2/19/97	GSFC	Muhonen
	NMP/EO1-I&T01	Ground System I&T Plan	Draft	1/14/97	3/1/98	GSFC	Kost
	NMP/EO1-FOP-01	Flight Operations Plan		12/1/97	2/1/99	GSFC	Kost
SAI-ICD-	EO1-ICD-XXX	S/C to ALI Instrument ICD	Draft 2	1/10/97	4/11/97	GSFC	Dardarian/ Zink
SAI-ICD-	EO1-ICD-XXX	S/C to PPT	Draft	1/10/97	4/11/97	Swales/ Litton	Callens/ Andrew
SAI-ICD-	EO1-ICD-XXX	S/C to Lightweight Flex Solar Array	Draft	1/10/97	4/11/97	Swales/ Litton	Vernot/ Andrew
SAI-ICD-	EO1-ICD-XXX	S/C to LEISA AC	Draft	1/10/97	4/11/97	GSFC	Perry/ Andrew
SAI-ICD-	EO1-ICD-XXX	S/C to Formation Flying SW	N/A	1/10/97	4/11/97	Litton/ Hammers	Hammers/ Baxter
SAI-ICD-	EO1-ICD-XXX	Satellite to Ground	N/A	1/10/97	4/11/97	GSFC	TBD
SAI-ICD-	EO1-ICD-XXX	Satellite to Launch Vehicle	N/A	1/10/97	4/11/97	GSFC	Callens
SAI-ICD-	EO1-ICD-XXX	S/C to GPS	N/A	1/10/97	4/11/97	GSFC	Quinn
SAI-ICD-	EO1-ICD-XXX	S/C to WARP	N/A	1/10/97	4/11/97	GSFC	Smith
SAI-ICD-	EO1-ICD-XXX	S/C to FODB	N/A	1/10/97	4/11/97	GSFC	TBD
SAI-ICD-	EO1-ICD-XXX	S/C to C-C Radiators	Draft	1/10/97	4/11/97	Swales	Coyle/Alea
S/C LEVEL DOCUMENTS							
SAI-PLAN-	EO1-PM-001	S/C Contract End Item Spec - WBS - S/C CEI Top Schedule - S/C CEI Project Plan	N/A	12/27/96	3/28/97	Swales	Cully
SAI-SOFT-	EO1-PLAN-001	ACS Software Development Plan	Draft		5/15/97	Litton/ Hammers	Hammers/ Baxter
SAI-SOFT-	EO1-PLAN-003	C&DH Software Development Plan	Draft	10/15/96	5/15/97	Litton/ DCS	Baxter
SAI-QA-	EO1-QA-001	Performance Assurance Plan	Draft 2	11/14/96	2/20/97	Swales	Davis
SAI-SPEC-	EO1-ENV-001	Environmental Specs	Draft			Swales	Carosso/ Hinshelwood
SAI-	EO1-SYS-001	Subsystem Allocations & Baseline Description	Draft	12/27/96	3/28/97	Swales	Perry
SAI-SPEC-	EO1-SYS-002	Electrical System Specification	Draft	Done	6/20/97	Swales/ Litton	Vernot/ Andrew
SAI-SPEC-	EO1-SYS-003	Avionics Subsystem Spec	Draft	4/18/97	6/60/97	Litton	Andrew

SAI #	ALT. #	DOC. TITLE	STATUS	PRELIM DUE DATE	FINAL DUE DATE	RESP. ORG.	RESP. PERSON
SAI-SPEC-	EO1-CDH-001	C & T Handbook	Draft		4/11/98	Swales/ Litton	Andrew/ Baxter
SAI-PLAN-	EO1-IT-PLAN-001	I&T Plan	Draft 2	11/14/96	6/20/97	Swales	Moyer
SAI-SPEC-	EO1-IT-002	Verification Plan & Test Spec	Draft	11/21/96	6/27/97	Swales	Hinshelwood
SAI-SPEC-	EO1-ACS-SPEC-XXX	ACS Component Spec - HW & SW	Prelim	4/18/97	7/18/97	Litton	Sanneman
SAI-SPEC-	EO1-COM-SPEC-XXX	COM Component Spec - HW & SW	Draft	4/18/97	7/18/97	Litton	Fielhauer
SAI-SPEC-	EO1-PWR-SPEC-XXX	PWR Component Spec - HW & SW	N/A	4/18/97	7/18/97	Litton	Wallace
SAI-STD-	EO1-PLAN-	CM Plan	Draft	11/21/96	12/27/97	Swales	Eisenhut/ Procaccino
SAI-PLAN-	EO1-PLAN-	Contamination Plan	Prelim			Swales	Carosso
SAI-PLAN-	EO1-PLAN-002	EO-1 SW Management Plan	Prelim		5/15/97	Litton	Baxter
SAI-SOW-011	EO1-SOW-001	EO-1 Reaction Control System SOW	Prelim		10/23/96	Swales	Callens
SAI-SPEC-110	EO1-SPEC-001	EO-1 Reaction Control System Specification	Prelim		10/23/96	Swales	Callens
		Ground Ops Control Procedures				Swales	
		Flight Operations Command / Telemetry Database and User's Manual				Swales	
		Spacecraft Description and Operations User's Manual				Swales	

Figure 2-1. Document References

Section 3. Technical Description

3.1 Flight System

The flight system consists of the launch, space and ground segments.

3.1.1 Launch Segment

EO-1 will be launched from the Western Test Range (WTR) at VAFB. The Launch Segment consists of the launch site, its facilities, and the launch vehicle. The Launch Segment also includes those services that are required during launch such as telemetry pass through from the launch vehicle. Post Shipment Checkout Testing, End-To-End testing and fueling are performed at the Payload Processing Facility (PPF).

At the TBD facility, the spacecraft is mated to the Delta 7320 Launch Vehicle. Prescribed tests and pre-launch operations are performed before the vehicle is declared ready for launch.

3.1.1.1 Launch Vehicle Overview

The launch vehicle for EO-1 is the McDonnell-Douglas Corporation Delta model 7320. This model of the Delta has a 10 foot diameter fairing, which will house the EO-1 spacecraft, the co-manifested Argentine Satellite de Aplicaciones Cientificas - C (SAC-C) spacecraft, and a Dual Payload Attach Fitting (DPAF). A graphical representation of the Launch Vehicle can be seen in Figure 3-1.

TBS

Figure 3-1. Delta Launch Vehicle

The launch will be from the Western Test Range (WTR) at Vandenberg Air Force Base, California. Figure 3-2 shows the timeline of launch events after liftoff. The table includes the initial ground station view periods, which are in the vicinity of Spitzbergen, Norway and Poker Flats, Alaska.

Event	Time (Min:Sec)	Altitude (km)	Inertial Vel. (m/s)	Latitude (deg)	Longitude (deg+W)
Liftoff	0:00	N/A			
Solid Motor Burnout (3)	1:04				
Solid Motor Separation (3)	1:50	37.6	882.4		
Main Engine Cutoff	4:21	98.2	4898.7		
Vernier Engine Cutoff	4:27	103	4904.2		
Stage 1-2 Separation	4:29	104.6	4900.9		
Stage 2 Ignition	4:35	108.9	4892.6		
Jettison 10 ft. Composite Fairing	5:00	126.5	4979.2		
First Cutoff - Stage 2 (Second Engine Cutoff 1)	10:48	187.1	7949.5	10.965	126.380
Stage 2 Restart	50:00	712.3	7365.8	-38.255	-48.727

Event	Time (Min:Sec)	Altitude (km)	Inertial Vel. (m/s)	Latitude (deg)	Longitude (deg+W)
Second Cutoff - Stage 2 (Second Engine Cutoff 2)	50:14	712.8	7501.7	-37.444	-48.483
Separate EO-1 Spacecraft	55:00	707.6	7504.2	-20.248	-44.019
Separate Portion of Dual Payload Attachment Fitting	59:10				
Separate SAC-C Spacecraft	63:20	705.2	7505.4	9.958	-37.462
AOS Spitzbergen, Norway *	76:24				
AOS Poker Flats, Alaska *	86:48				
LOS Spitzbergen *	87:58				
LOS Poker Flats*	97:52				
Second Stage Evasive Burn Ignition	100:00				
Third Cutoff - Stage 2 (Second Engine Cutoff 3)	100:05				
Second Stage Depletion Burn Ignition	108:20				
Stage 2 Depletion	109:00				

* Elevation 5 Degrees

Figure 3-2. Timeline of Launch Events

3.1.2 Space Segment

The EO-1 Space Segment is comprised of the Dual Payload Attach Fitting (DPAF), the Ground Support Equipment (GSE), and the Satellite.

The DPAF provides the mating interface between the two satellites (EO-1 and SAC-C) and launch vehicle and for their mechanical separation. Springs contained in the DPAF impart a separation velocity of 1-2 feet/second with tip-off rates less than 0.5°/second.

The Ground Support Equipment (GSE), consists of several pieces of equipment used by the spacecraft builder during the building and testing of the spacecraft. This equipment includes a satellite checkout station, the launch support equipment, flight software special test equipment, and the ALI interface equipment.

The following subsections provide a brief overview of the spacecraft subsystems and instrument. Detailed descriptions of the spacecraft will not be given in this document as they exist in the “On-Orbit Handbook” (TBS) and various Critical Design Review (TBS) packages. The subsystems that comprise the spacecraft are as follows:

- Structure
- Power
- Command and Data Handling
- Attitude Determination and Control
- Communications
- Thermal Control
- Propulsion
- Deployables
- Advanced Land Imager (ALI) and Atmospheric Corrector Add On

Section 3.1.2.1 provides a graphical description of the EO-1 spacecraft.

3.1.2.1 Spacecraft Description

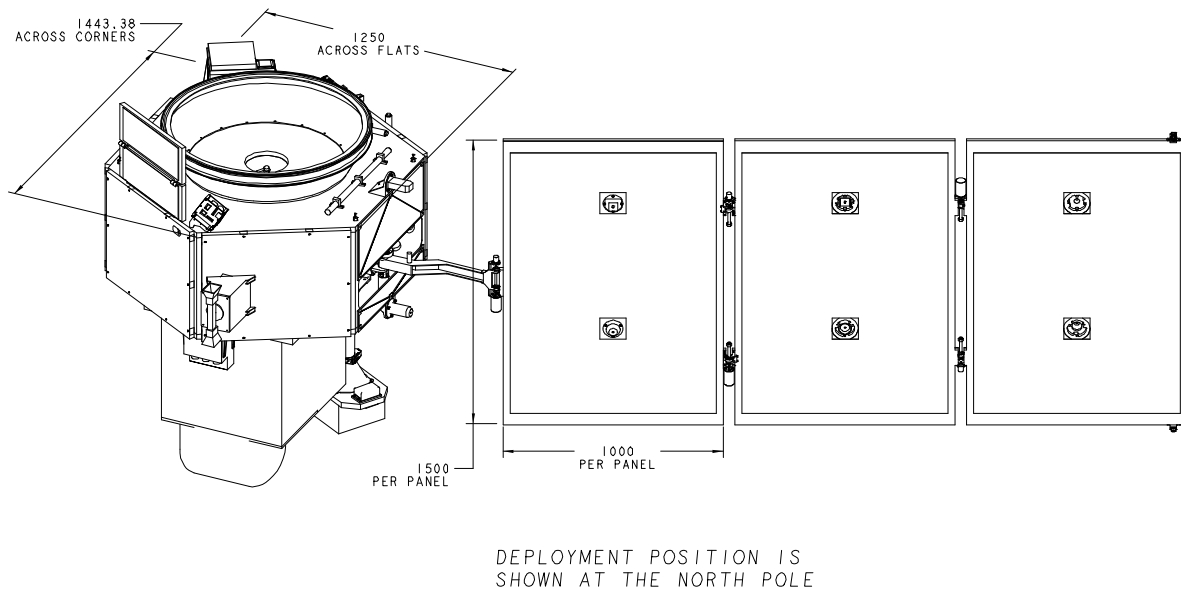


Figure 3-3. Deployed Spacecraft With Coordinate System (Sun Normal To Page)

3.1.2.2 Spacecraft Structures

The spacecraft primary structure is made entirely of composite material. There is a series of radial shear panels with lateral struts all composed of high stiffness/low distortion graphite epoxy lay-ups. The shear panels are held at the ends by a hexagonally shaped base panel and a payload deck. There are also a number of equipment panels which are mounted on the circumference to support the subsystem equipment. The design of these panels facilitates easy integration through the use of ground support hinges mounted on the side of each panel. This arrangement represents an open architecture which is well suited for the subsequent incorporation of advanced technologies.

3.1.2.3 Power Subsystem

The Electrical Power Subsystem (EPS) provides the ability to generate, store, switch, and distribute power as needed by the spacecraft. A pyrotechnic system, launch vehicle interface support, and special test interfaces are also provided.

Power is supplied by a single gallium arsenide photovoltaic array with a peak power output of about 600 watts. This array articulates about the spacecraft Y axis at the orbital rate with an unwind occurring during each eclipse. The array boom is slightly angled to compensate for the solar beta angle. The accompanying nickel-cadmium battery has a capacity of 50 Ah and is composed of TBS cells in series. The power system electronics is based on a flexible design that

Control Electronics RSN MIPS UT69R000 microprocessors reside in the ACDS box. The Power System Electronics RSN resides in the Power System Electronics box.

Science data from the ALI and the Atmospheric Corrector is re-ordered in the WARP. The WARP contains both a Mongoose V and a RSN.

The 40 Gbytes of storage provided by the WARP for payload data will accommodate TBD minutes of scene taking. The 1.8 Gbits available for housekeeping data in the Mongoose V is enough to store 27 hours of data.

Communication throughout the spacecraft is accomplished with a 1773 fiber optic star network and the instruments are located on a newly developed fiber optic data bus in a ring configuration. It has "plug and play" characteristics and can support data rates up to one Gbps. If focal plane sensors and their associated memories are located next to each other on the ring network, then the data bus can simultaneously support up to one Gbps between adjacent sensors and their associated memories. The total data rate from the ALI instrument and the Atmospheric Corrector is slightly less than 0.9 Gbps. Associated with the data handling is a separate solid state recorder which interfaces with the instrument and provides 40 gigabits of solid state storage.

Figure 3-5 provides a simplified block diagram of the C&DH subsystem.

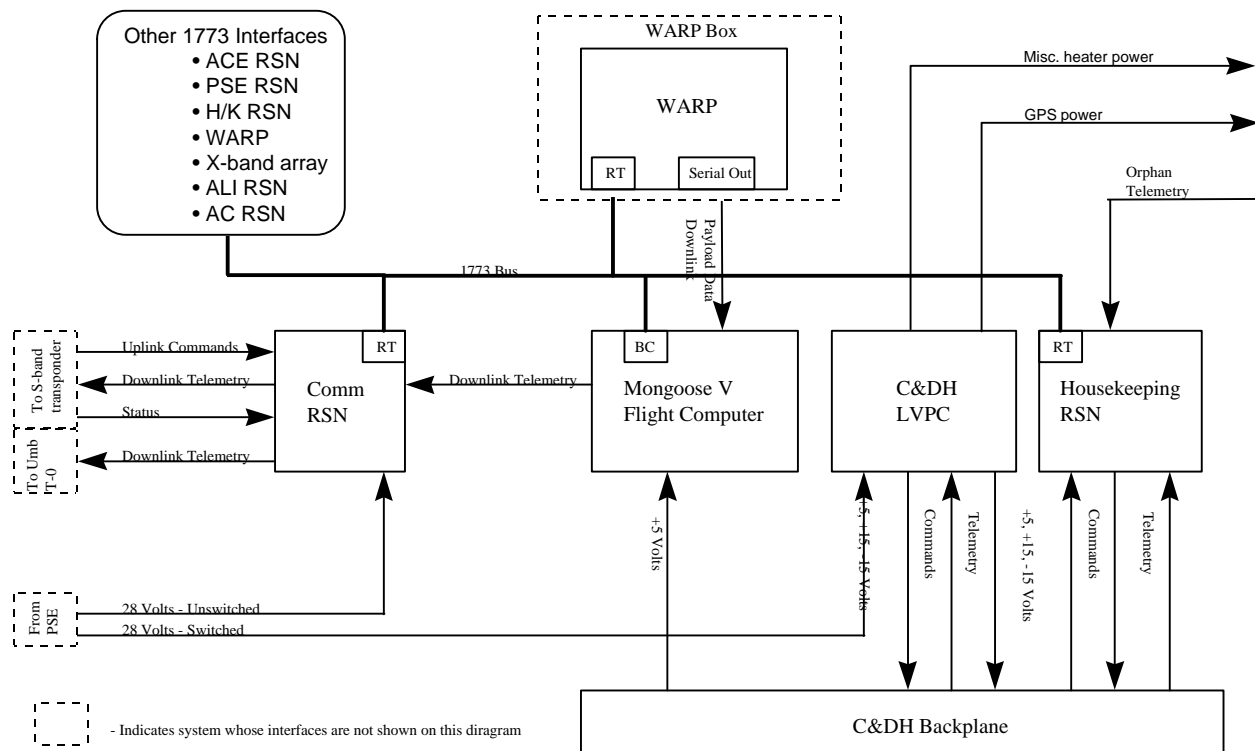


Figure 3-5. C&DH Block Diagram

3.1.2.5 Attitude Determination and Control Subsystem

The purpose of the Attitude Determination and Control Subsystem (ADCS) is to establish and maintain a stable platform from which the instrument may perform accurate remote sensing, as well as to keep a specified distance from Landsat 7 so that compared scenes can be taken. It uses a closed loop system with sensors feeding measured attitude errors to a processing function which calculates the necessary restorative torques and implements them via commands to the chosen actuators. The basic pointing accuracy in the yaw axis is 0.022 degrees-2 sigma. The roll and pitch are in the range of 0.05-0.15 (TBD) degrees, 3-sigma. ADCS components are listed below:

- Sensors
 - Gyros
 - Sun sensors
 - Star tracker
 - Global Positioning System (GPS) receiver
- Actuators
 - Reaction wheels
 - Magnetic torque rods
 - Thrusters

The interface between the sensors and the actuators is located in the C&DH subsystem. Tools needed by the ADCS are the daily ephemeris file loaded by ground personnel as well as TBS.

The GPS receiver has an additional function to provide on-board orbit determination for use with the orbit control operations. It is planned to include within the spacecraft an autonomous capability to maintain the EO-1 orbit in a close formation with Landsat-7, thus enabling the taking of nearly identical imaging scenes from the two spacecraft for instrument validation. During the nominal 12 month mission, Formation Flying will be performed using ground computations from the AUTOCON program.

Figure 3-6 provides a high level block diagram of the ADCS.

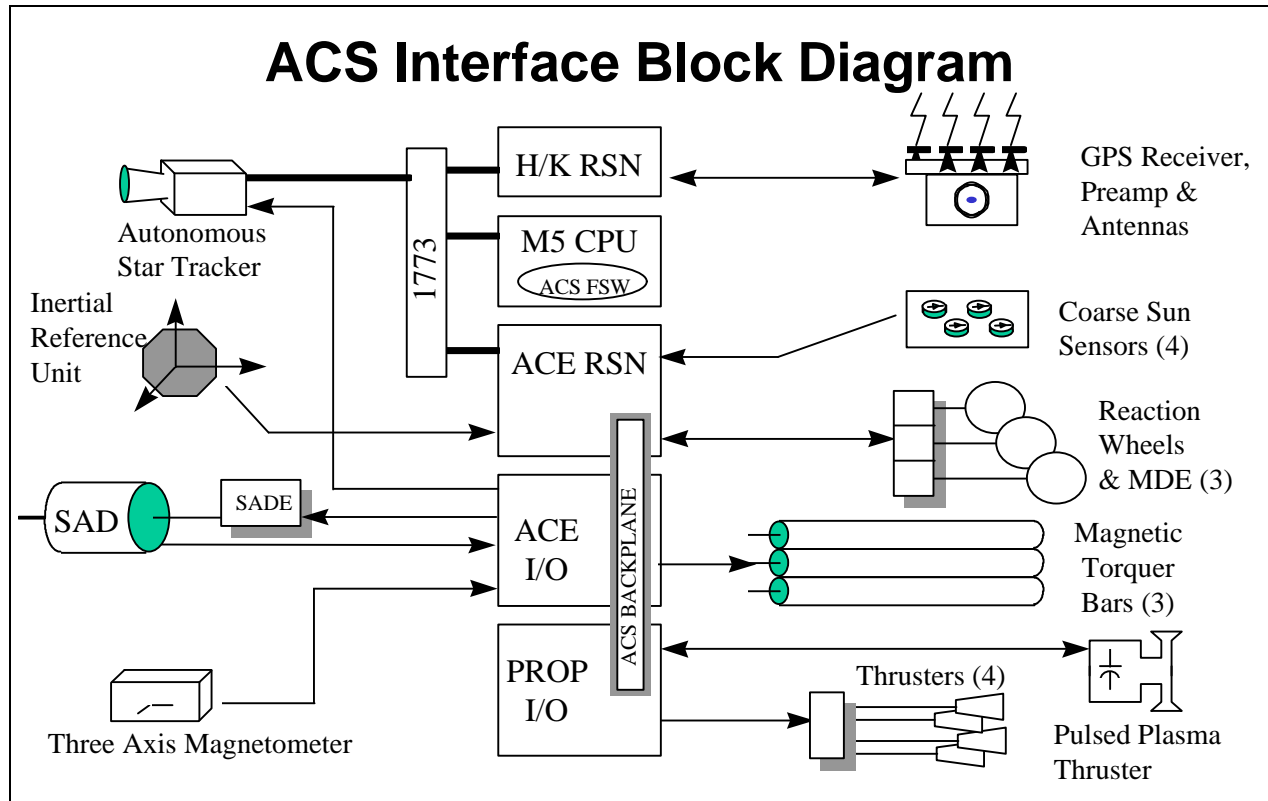


Figure 3-6. ADCS Block Diagram (TBS)

3.1.2.6 Communications Subsystem

The communication subsystem has both X and S-band capabilities. The spacecraft has S-band omni-directional antennas and GPS patch antennas on both nadir and zenith-pointing surfaces. The S-band is intended for both command and control and housekeeping telemetry. As one of the new technologies, a 64-element X-band phased array antenna is located on the nadir-pointing surface of the spacecraft. Imaging data will nominally be down-linked at a high data rate via the X-band system, but a backup capability is provided to down-link the data at a reduced rate via S-band. The primary ground station, located at Spitzbergen, Norway, will use an 11 meter antenna. Backup and launch support will be provided by stations in Alaska, Wallops, and McMurdo, Antarctica. The data rates supported between the ground stations and spacecraft can be seen in Figure 3-7.

Data Type	Data Rate
Uplink	2 Kilobits/sec
Downlink X-band Science	105 Megabits/sec
Downlink S-band real time and recorded HK	1000/32/2 Kilobits/sec
Downlink S-band backup Science	4 Megabits/sec

Figure 3-7. Spacecraft Data Rates

Figure 3-8 illustrates the RF system.

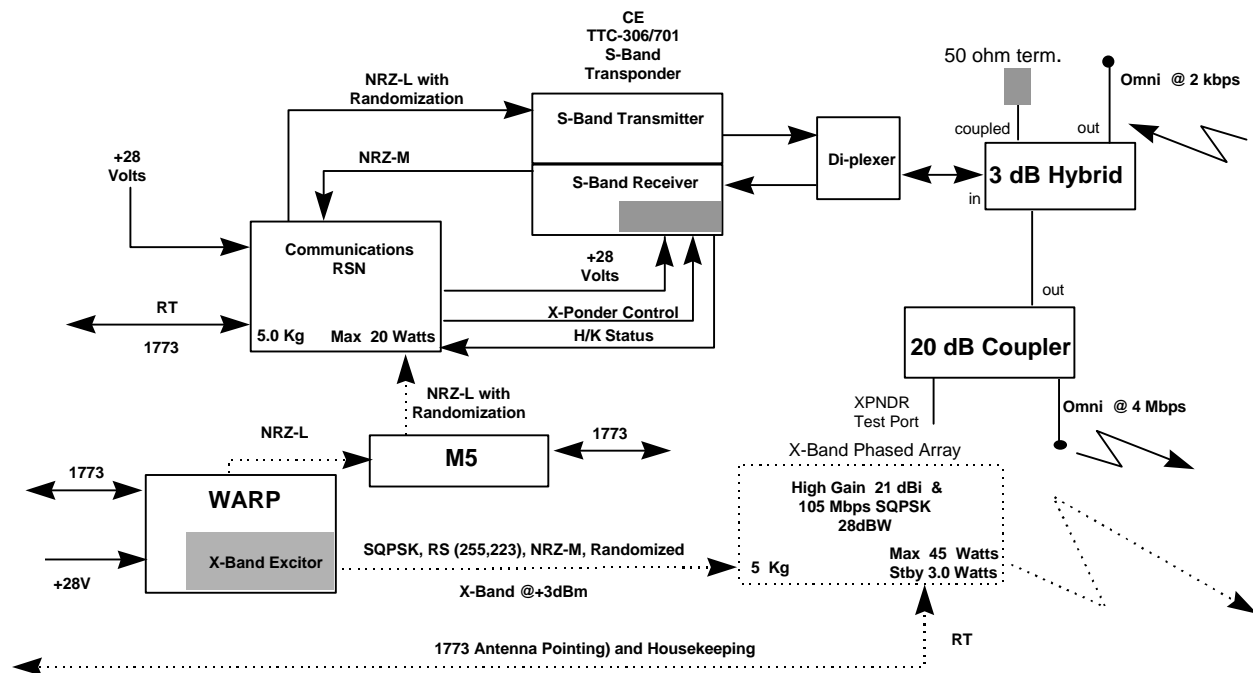


Figure 3-8. RF Communications Subsystem Block Diagram

3.1.2.7 Thermal Control Subsystem

The spacecraft thermal subsystem is a cold biased design which is thermally isolated from the instrument. Heaters will provide thermal control for components when they are not in operation or will provide tighter thermal control for more critical components. Associated with the thermal system are carbon-carbon radiators which will validate the use of these devices in the space environment. This material has both high strength and high thermal conductivity and promises future radiators which will be significantly lighter than their aluminum counterpart.

3.1.2.8 Propulsion Subsystem

The Reaction Control Subsystem (RCS) provides the propulsion capability required for orbit maintenance, and attitude control during orbit maneuvers. The RCS also provides the capability to perform back-up momentum wheel unloading.

Propulsion is provided by a hydrazine "blow-down" subsystem using four 0.2 pound thrusters. The propulsion subsystem carries 22.5 kg of hydrazine which will support initial orbit adjustments, station keeping, rendezvous maneuvers, and formation flying with Landsat 7. Associated with the propulsion system is one of the new technologies which involves a small, self-contained electromagnetic propulsion unit that uses solid Teflon as a propellant. It produces an I_{sp} of 1000-2000 seconds and will be used experimentally to replace the pitch reaction wheel to maintain attitude control.

Figure 3-9 provides a functional diagram of the RCS.

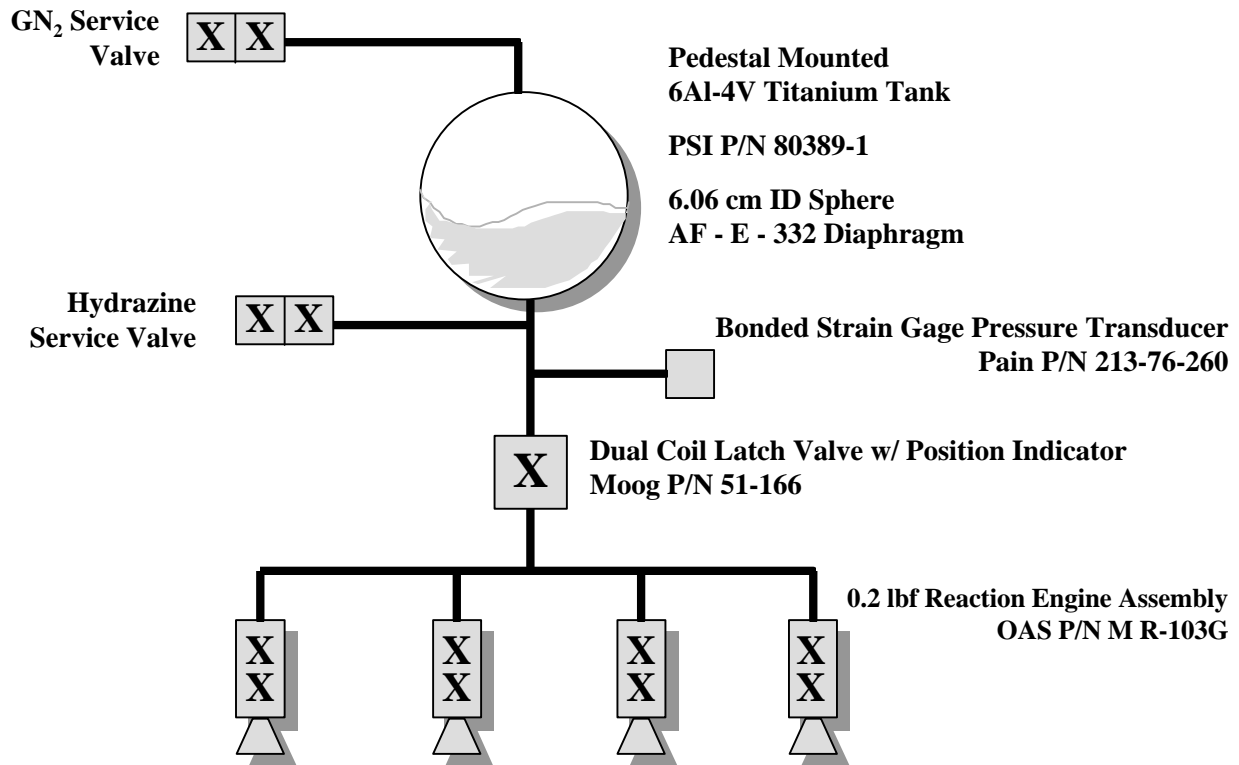


Figure 3-9. Reaction Control Subsystem Block Diagram

3.1.2.9 Instrument Description

The baseline features of the Advanced Land Imager (ALI) are considered fundamental to the Flight Objectives listed above. It employs a "pushbroom" combination of multispectral and hyperspectral capabilities ranging from 0.4 to 2.5 micrometers. A single, integrated, and non-cryogenically cooled focal plane is partially populated by both multispectral and hyperspectral sensor chip assemblies (SCAs). There are four multispectral SCAs which image a combined swath of 60 km width over ten Landsat-like bands (Pan and TM equivalent bands: 1', 1, 2, 3, 4, 4', 5, 5', and 7). The resolution is 10 m in the pan band and 30 m in the remaining bands.

The hyperspectral capability is divided into two SCAs: one covers the spectrum from 0.4 to 1.0 micrometers and the other covers from 1.0 to 2.5 micrometers. These hyperspectral SCAs represent a hybridization of a linear variable "wedge" spectral filter and a two dimensional focal plane array. This approach will provide small, lightweight, and readily affordable detectors for future missions. These hyperspectral SCAs image a 9.6 km swath with 30 m resolution. The two hyperspectral SCAs have a combined total of 315 bands. The combined data output from both the multispectral and hyperspectral SCAs amounts to 383 Mbps, assuming 12 bit samples throughout.

The ALI also contains a miniature hyperspectral grating spectrometer which incorporates a novel compact optical design that integrates the visible and infrared focal planes. It provides simultaneous spectral sampling of all 210 channels for each 30-m pixel which guarantees a spectrally registered data set and enables sub-pixel material identification. The data rate from the miniature grating hyperspectral spectrometer is 276 Mbps. The hyperspectral grating spectrometer and the hyperspectral wedge spectrometer are so situated that they view the same ground track through the same optics from the same instrument. This arrangement is designed to provide a comprehensive validation of the hyperspectral wedge technique based on a comparison of these two hyperspectral imaging techniques. An important feature of this comparison concerns small misalignments between the hyperspectral wedge sensor and the spacecraft velocity vector during the time the image is being gathered. These misalignments can cause spectral corruption for which knowledge of the misalignment is insufficient to provide a suitable correction. The grating spectrometer is not subject to this form of spectral corruption and, in this regard, serves to validate the hyperspectral wedge spectrometer and also serves as a second source of hyperspectral imaging data. The algorithms developed for AVIRIS (a previously developed grating spectrometer) can also be applied to the data from the EO-1 grating spectrometer, effectively leveraging a large investment in data processing software and ensuring rapid, meaningful evaluation of the EO-1 hyperspectral data.

FUNCTIONAL BLOCK DIAGRAM

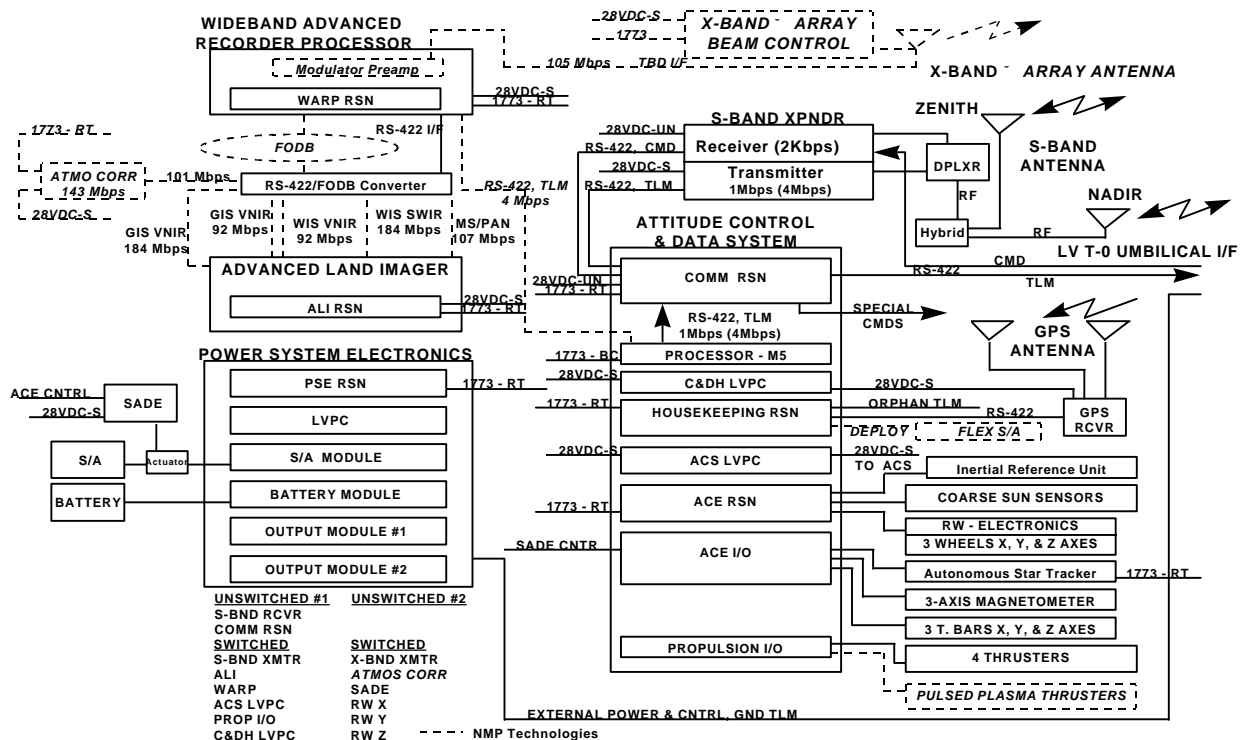


Figure 3-10. EO-1 Electronics Block Diagram

NOTE:

For an explanation of the acronyms used in this Figure, see the Spacecraft DCR.

The optical system is a three mirror anastigmatic system held in an optical truss with both the mirrors and the truss being made of hot pressed silicon carbide. This approach provides a light, stiff, and thermally stable optical system. The aperture is 12.5 cm. The field of view is 1 degree by 15 degrees which corresponds to a 185 km swath on the ground. The optical system is complete even though the focal plane is only partially populated.

The four multispectral SCAs are at one end of the focal plane and the two hyperspectral SCAs are in the center of the focal plane looking in the nadir direction.

The calibration system is designed to validate approaches to ensure a long-term radiometric calibration of 5% or better. There are six separate calibration modes that can be evaluated during the mission. The first of these is solar calibration through the use of a diffuse reflector that can be inserted into the optical path by command while pointing at the sun is maintained to within 0.25 (TBD) degrees. The second method involves scanning across the lunar surface. The third method involves the imaging of areas on the ground of known reflective characteristics. The fourth method involves minimal signal achieved by looking into deep space. The fifth method also involves minimal signal and is achieved by commanding the closure of an aperture cover. The sixth method entails the use of a calibrated internal source.

The baseline instrument weighs 55 kg, operates on 75 w, and fits in a volume of 0.2 cubic meters.

The Atmospheric Corrector is a "bolt-on" accessory to the ALI instrument. It is small and has a simple interface such that its "bolt-on" capability makes it applicable to a variety of imaging systems wherein atmospheric correction can enhance the value of the imaging data. It consists of a second hyperspectral wedge spectrometer located over a two dimensional focal plane array. It covers the entire 185 km swath with a resolution of 250 m and it is boresighted to the ALI instrument to within 1/4 degree. It weighs less than 6 kg and operates on 25 w. It is designed to provide simultaneous atmospheric correction for the images being gathered by the ALI instrument. It provides correction for water vapor and some aerosols. The data rate from the Atmospheric Corrector is 80 Mbps.

See Figure 3-11 for a graphical representation of the instrument. Table 3-12 shows ALI spectral band assignments.

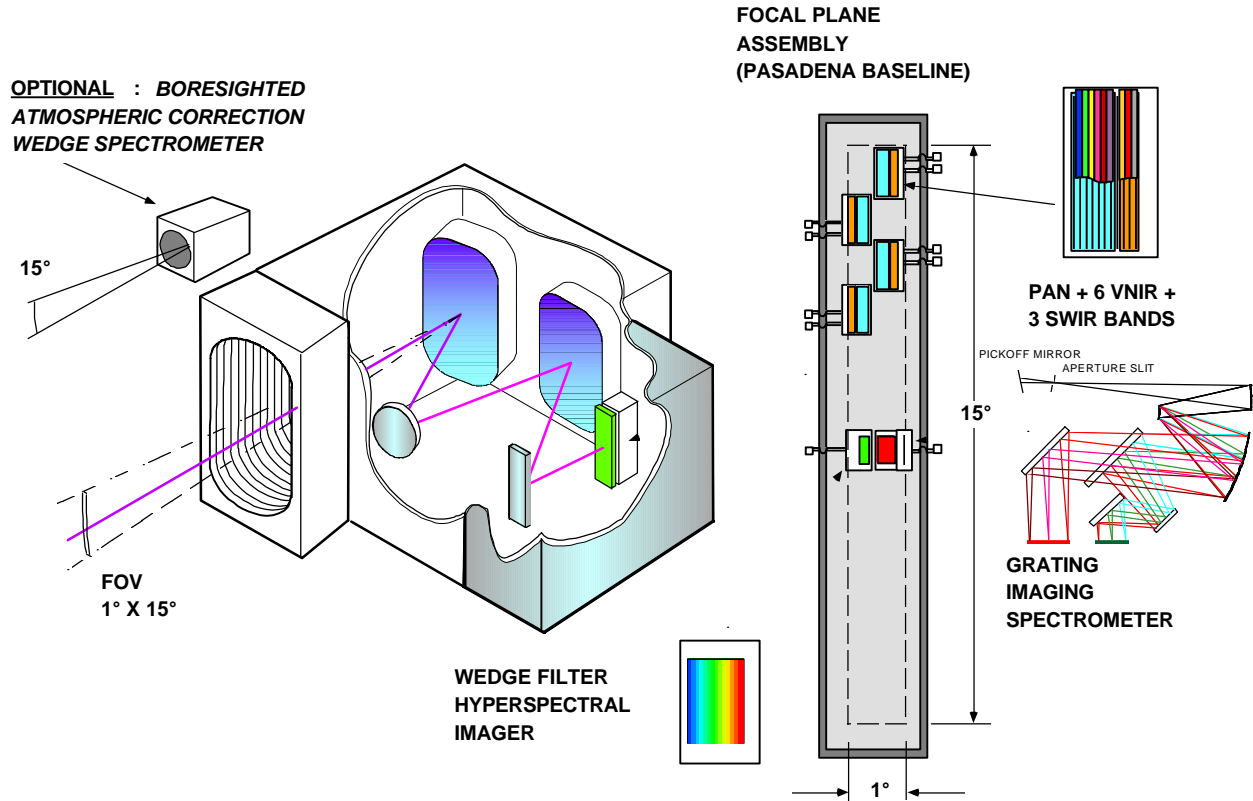


Figure 3-11. ALI

Spectral Band	Lower and Upper Band Edge in Microns (50%)	Ground Sample Distance (m)
PAN	0.480-0.680	10
1'	0.433-0.453	30
1	0.450-0.515	30
2	0.525-0.605	30
3	0.630-0.690	30
4	0.775-0.805	30
4'	0.845-0.890	30
5'	1.20-1.30	30
5	1.55-1.75	30
7	2.080-2.350	30

Figure 3-12. ALI Spectral Band Assignment and Resolution

3.2 Ground System

The ground system, which is shown in Figure 3-13, consists of the following:

- Autonomous Mission Operations Center (MOC) at GSFC, which includes:
⇒ Mission Command and Control (MCC) System.

- ⇒ The Level-0 Processing (LZP) System.
- ⇒ Flight Dynamics System (FDS).
- EO-1 Ground station Network, which includes:
 - ⇒ NASA Communications (Nascom).
 - ⇒ Automated Orbital Tracking Station at Spitzbergen, Norway (Prime support).
 - ⇒ Automated Orbital Tracking Station at Poker Flats, Alaska and Wallops Flight Facility (Backup and Launch support).
 - ⇒ Automated Orbital tracking station at McMurdo, Antarctica (Launch support, Maneuver support, and Technology Demonstration).
 - ⇒ The Tracking Data Relay Satellite System (TDRSS) / White Sands Complex (WSC) to receive and forward spacecraft telemetry for launch support.
- Science Data Center (SDC) at GSFC.
- Land Processes Distributed Active Archive Center (LP DAAC) at Sioux Falls, Iowa.

3.2.1 NMP EO-1 Mission Operations Center (MOC)

The EO-1 MOC, located at TBD, will be an extension of the Midex MOC design. It provides the hardware and software systems necessary for the successful execution of real-time spacecraft operations and off-line scheduling and analysis activities. All command and control functions of the spacecraft will take place from the MOC. From the MOC, the Flight Operations Team (FOT) will ensure that spacecraft conditions are monitored and controlled. Along with ensuring the health and safety of the spacecraft, the FOT will schedule and execute science data capture, retrieval, and processing to Level 0. The FOT, using MOC tools, will facilitate resource scheduling and interface with the appropriate elements required to conduct mission operations and meet the mission objective.

The MOC also contains the FDS which provides orbit determination verification for the on-board GPS orbit determination solutions, backup S-Band orbit determination, performance assessments of on-board attitude determination and control, sensor calibration, orbit maneuver support for S-Band tracking pre-processing, and planning and scheduling product generation.

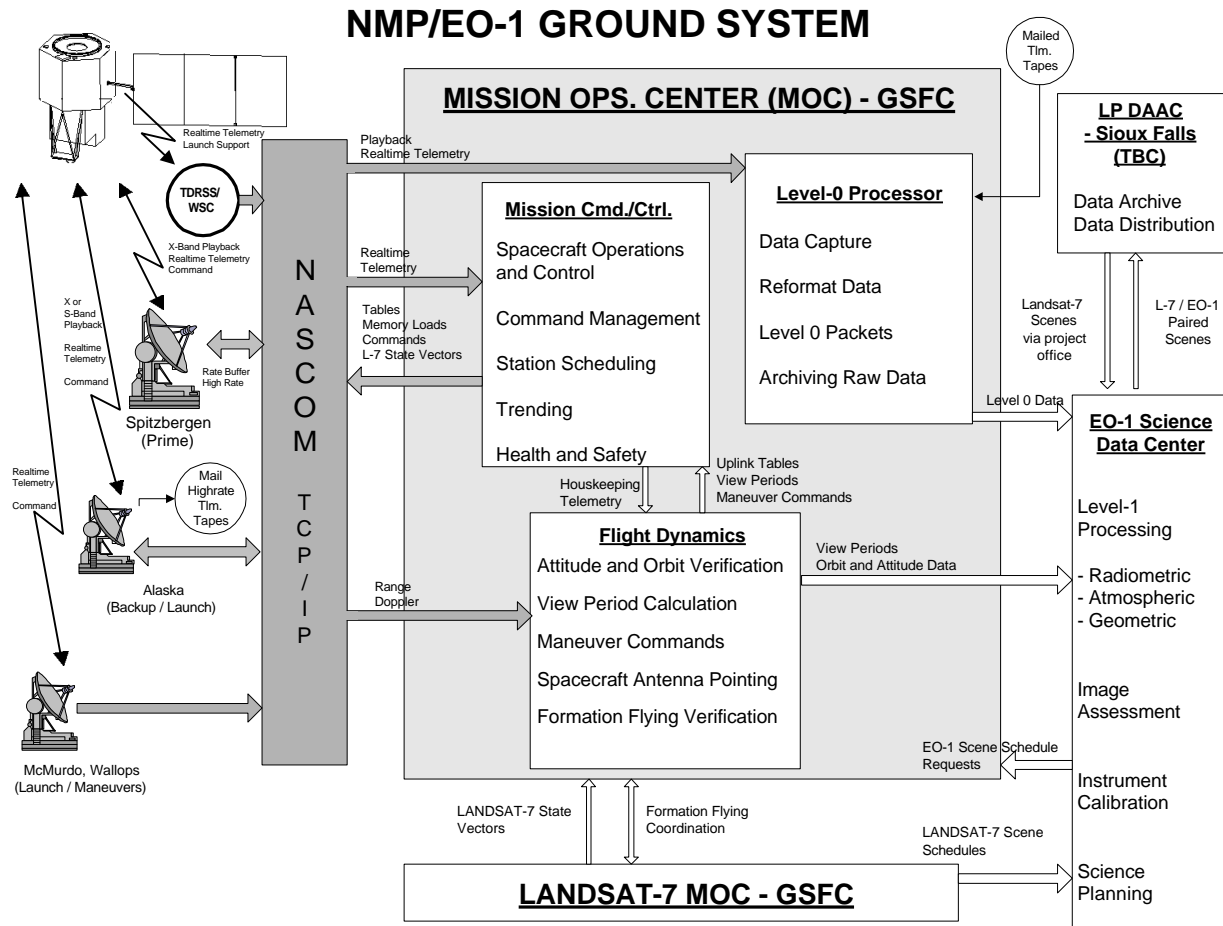


Figure 3-13. NMP EO-1 Ground System

3.2.1.1 Mission Command and Control System (MCC)

The MCC will be used for planning and scheduling of spacecraft operations, spacecraft command and control, monitoring and maintenance of spacecraft health and safety, parameter trending, spacecraft performance analysis, onboard solid state recorder management, and flight software maintenance operations. Commands and loads will be entered and processed for up-link to the spacecraft, and telemetry will be monitored in near real time by the FOT. Autonomous features will be incorporated in the MCC design to enable single-shift FOT staffing.

3.2.1.2 Level-0 Processing (LZP) System

The function of the LZP is to provide data capture and level-0 processing for both the high rate playback science data and the real-time housekeeping data. All raw data will be received by electronic transmission, although the high rate data will be rate-buffered or mailed on tape and received with some delay. The high rate data will require decompression, and some of the instrument housekeeping data may require re-formatting to Standard Formatted Data Units

(SFDU). Image data may require additional re-formatting (TBD) before transfer to the SDC, and it is expected that the remaining Level-0 data will retain the CCSDS packet structure of the telemetry. All raw data will be archived by the LZP.

3.2.1.3 Flight Dynamics System (FDS)

NMP EO-1 is designed to perform autonomous orbit determination and maneuver operations utilizing the GPS receiver and the Autonav system, which can control the Enhanced Formation Flying experiment. During the 12 months of the nominal mission, the FDS will perform computations from the ground to control the formation flying as an “open loop”. The FDS will be used in the validation of these functions, and maneuver commands will be executed “open loop” from the ground during checkout and if the on-board system fails. The entire formation flying process will be closely monitored via the FDS. The FDS will also be used to generate ground station view periods and other scheduling aids, spacecraft antenna pointing angles, attitude products for image processing, and ADCS calibrations.

3.2.2 NMP EO-1 Ground Station Network Support

Nominally, telemetry will be down-linked in both X and S-band, simultaneously, although occasionally only one band (X or S) will be used. All telemetry and command data follow CCSDS standards. Commanding and ranging will be simultaneous with the S-band housekeeping telemetry. If there is a failure onboard with the X-band (science), both science and housekeeping telemetry will be down-linked in S-band in a high data rate, backup mode. The principal spacecraft interface characteristics of the telemetry and command are listed below:

	X-BAND TLM.	S-BAND TLM.	CMD. (S-BAND)
NOMIN. DATA RATE:	105 Mbps (S)	4000, 1000, 32, 2 Kbps (H)	2 Kbps
NOMIN. DATA VOL.:	80 gigabits/day	1 gb/day PB+RT (H)	
BACKUP DATA RATE:		4 Mbps (S/H)	2 Kbps
BACKUP DATA VOL.:		10 gigabits/day (S)	
LAUNCH DATA RATE:		1 gigabit/day (H)	
ANTENNA BEAM:	9 deg	2 or 32 Kbps	2 Kbps
ANTENNA GAIN:	17 dBi	360 deg	
TRANSMIT. POWER:	5 watts	3 dBic	
		5 watts	

S = Science Telemetry

H = Housekeeping Telemetry

SH = Science and Housekeeping Telemetry

Figure 3-14. Spacecraft Command and Telemetry Parameters

The 11-meter Automated Orbital Tracking Station at Spitzbergen, Norway will be baselined as prime for all X/S-band ground station support, with backup from the 11-meter station located near Fairbanks, Alaska or at the Wallops Flight Facility in Virginia. One or two contacts per day, each 10 minutes duration, will be scheduled. In case of X-band failure, the Alaska 11-meter station, or possibly one of the two TOTS systems at Poker Flats, Alaska, will be used, with 45 minutes per day contact, S-band only. Launch support (S-band only) will be provided by the Tracking Data Relay Satellite System (TDRSS)/ White Sands Complex (WSC), Wallops, Alaska,

Spitzbergen, Norway, McMurdo, Antarctica, and the Wallops Flight Facility in Virginia. McMurdo will be used for maneuver support and may also be used during the mission for technology demonstrations. The principal ground station interface characteristics are shown in the following table.

	Spitzbergen	Wallops	Alaska/ 11-meter	Alaska/ TOTS	McMurdo
ANTENNA DIAMETER	11 meter	11 meter	11 meter	8 meter	10 meter
FREQUENCY BAND	S/X	S/X	S/X	S only	S/X
G/T(dB/K)	23	23	23	21	23
EIRP(dBmi)	96	96	96	93	94

Figure 3-15. Ground Station Characteristics for EO-1 Operations

3.2.2.1 NASA Communications (Nascom)

All telemetry and command data between the MOC and the ground stations will be transmitted by electronic ground communications services provided by Nascom. Sufficient bandwidth may be required to enable rate-buffering of the high rate telemetry data. The interface will be TCP/IP.

3.2.2.2 Ground Station Operations

The Wallops, Alaska, Spitzbergen, and McMurdo ground stations each provide an electronic interface between a spacecraft and its user 24 hours per day, 365 days per year. NMP/EO-1 will utilize a new Nascom TCP/IP interface that is expected to be available in early 1997.

The real-time telemetry data, which is included as separate virtual channels in S-band down-link, will be delivered in real-time or near real-time. The playback image data (105 Mbps X-band and 3 Mbps S-band backup) will be recorded on site, temporarily archived, and rate-buffered to the MOC over data links of sufficient bandwidth. Commands will be throughput to the spacecraft upon receipt at the station. Scheduling between the MOC and the ground stations will utilize the Wallops Scheduling Group via the Internet.

3.2.3. NMP EO-1 Science Data Center (SDC)

The SDC, located at GSFC, provides an off-line function to generate level-1 EO-1 imager scenes, and make comparisons with, and appropriate corrections to, corresponding scenes from Landsat 7. Formation flying with Landsat 7 will enable the same scenes to be taken from both spacecraft at nearly the same time and under nearly the same environmental conditions. The EO-1 scenes will be processed through radiometric, atmospheric, and geometric correction processes. Paired EO-1/Landsat 7 scenes will then be sent to the LP DAAC for archiving and distribution. The SDC will also provide instrument calibration data and requests to the MOC for instrument calibration scene collection. SDC operations are covered in greater detail in Section 6.

3.2.4. *Earth Resources Observation System (EROS) Data Center (EDC) Land Processes Distributed Active Archive Center (LP DAAC)*

The LP DAAC, located at Sioux Falls, South Dakota, will provide Landsat 7 scenes to the SDC and permanently archive the EO-1/Landsat 7 paired scenes and associated data generated by the SDC (TBC). On request from a registered customer, it will compile and format data desired by the customer for distribution and perform the appropriate billing and accounting functions. The LP DAAC will also make browse data and metadata (TBC) available to potential users (TBC).

Section 4. Normal Operations

4.1 Mission Operations Description

Because autonomy will be a significant aspect of both the spacecraft and the ground system designs, it is expected that the operational staffing will not exceed 1-3 people for one shift, five days per week. One new technology will be GPS-based and will allow EO-1 to maintain a separation of several minutes behind Landsat 7 using computations performed by the FDS system on the ground. This can validate the concept of formation flying and also serve to enhance the value of the paired scene comparisons with Landsat 7. Figure 4-1 shows the EO-1 orbit and how it relates to Landsat 7.

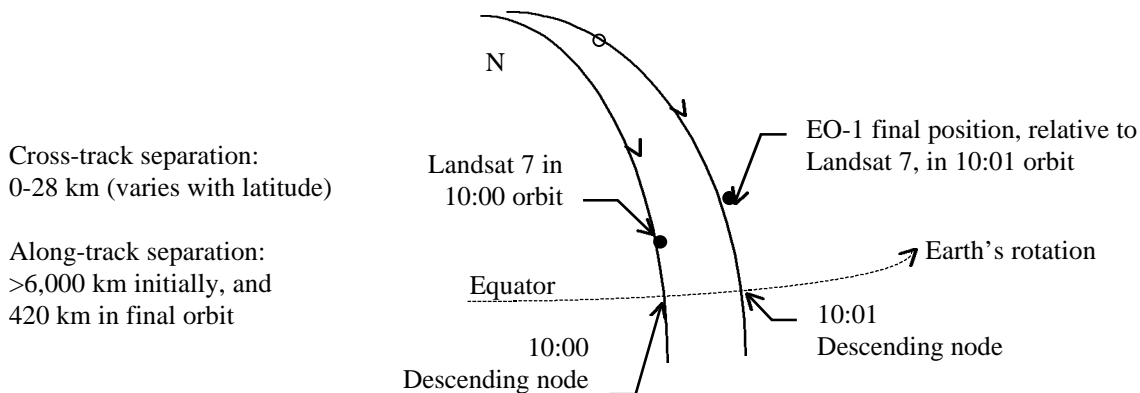


Figure 4-1. EO-1 Orbit Relative to Landsat 7

The scenarios and accompanying explanations that appear in this section represent those actions that elements of the NMP EO-1 Ground System (EGS) must nominally perform to ensure that the NMP EO-1 mission is accomplished, on both a continuing and periodic basis. Section 5 deals with launch activities and those activities that need to occur during launch and when either the satellite's or the Ground System's functionality is disrupted and emergency operations need to be invoked. The following high-level requirements will be satisfied during nominal operations:

- Spacecraft health and safety monitoring and control (commanding and telemetry).
- Spacecraft onboard computer maintenance and stored command processor uploading.
- Orbit and attitude determination for validation of the on-board systems.
- Imaging operations (planning and commanding), including the capture, processing to level-0, and archiving of raw data for one or two scenes (up to 80 gigabits) of image data per day (excluding weekends and holidays).
- The MOC shall plan and schedule payload and spacecraft operations, considering:
 - ⇒ Schedule requests from the SDC for image scenes.
 - ⇒ 40 gigabits capacity of the onboard recorder.

4.1.1 Mission Operations Phases and Modes

The phases and modes for spacecraft operations are summarized in this section. The EO-1 mission has seven mission phases as identified in Figure 4-2, which describes the events and modes that occur during each phase of the mission.

Mission Phase	Events	Spacecraft Modes
Pre-launch Planning and Testing	Development of requirements, implementation of requirements via development and operation of system.	Test
Launch and Early Orbit Checkout	Final on-launch preparations; launch, launcher trajectory, injection, separation. EO-1 activation, stabilization, deployment, initial acquisition, mission orbit insertion.	Pre-launch Ascent Initial acquisition Normal Orbit adjust Safe
On-orbit verification	Checkout and calibration of spacecraft and instruments Validation of spacecraft control	Normal Calibration Safe
Early formation flying/normal operations	Maintain approximately 15-minute separation with Landsat 7 Spacecraft performance demonstration	Orbit adjust Normal Safe Special technology
Late formation flying/normal operations	Maintain close separation (as close as one minute) Science validation of ALI	Orbit adjust Normal Safe Special technology
Extended mission	TBD, after one year of operations	Orbit adjust Normal Safe Special technology

Figure 4-2. Mission Phases and Modes

Once the errors are corrected from launch-vehicle insertion (Orbit Adjust mode), ground operations will check out the spacecraft, and then formation flying, and the normal operations phase will commence. The Calibration mode will be used periodically throughout the mission, and will include both Solar and Lunar calibration. Normal mode operations will include Standby, Science Data Collection, and RF Communications functions. Periodically, the mission will enter the Orbit Adjust mode or the Calibration mode, as required. The Safe mode is entered automatically by the satellite in the event of a satellite anomaly. The Special Technology Test and Evaluation mode is a place-holder for testing NMP Category-3 technologies that are not tested during other modes. The best example of this mode is testing the use of the PPT as part of the attitude control system.

4.1.1.1 Pre-launch Planning and Testing Phase

The pre-launch planning and testing phase emphasizes ground segment implementation, testing, flight operations planning and team training. This phase also includes activities required for final observatory checkout and launch site operations. Operations success criteria during this phase include the following:

- Complete documentation of EGS requirements.
- Development of the EO-1 Flight Operations Plan.
- Development, population, maintenance, and distribution of the Project Data Base (PDB).
- Development of tools required for testing and Flight Operations Team (FOT) training.
- Testing of all ground system elements.
- Staffing, training, and certification of element operations teams.
- Development of detailed flight procedures (both normal mission and contingency operations) and all necessary displays.
- Presentation of Mission Operations Review (MOR).
- Successful completion of scheduled End-to-End tests, involving all operational ground elements, with the EO-1 spacecraft.
- Certification of an 'Operations Ready' ground system via the Operations Readiness Review / Flight Operations Review (ORR/FOR).
- Completion of the EO-1 L&EO Operations Plan.
- Presentation of L&EO checkout plan at the Operations Readiness Review / Flight Operations Review (ORR/FOR).
- Certification of a 'Launch Ready' ground system and space segment via the Operations Readiness Review / Flight Operations Review (ORR/FOR).
- Plan and execute several operations simulations for FOT training and system checkout.
- EO-1 transport to the WTR launch site.
- Satellite checkout, end-to-end testing, and launch rehearsal from launch site.

4.1.1.2 Launch and Early Orbit Operations Phase

This phase is a combination of the Launch and Early Orbit Checkout, and On-orbit verification phases. The Launch and Early Orbit (L&EO) Operations phase begins at launch and extends approximately 30 days. The emphasis during this phase is on EO-1 launch, deployment and stabilization, satellite checkout, achieving mission orbit, and any power-up/calibration operations necessary for the ALI, Attitude Determination and Control Subsystem (ADCS), and other satellite hardware. Operations success criteria during this phase include the following:

- Nominal Delta 7320 launch, orbit insertion and EO-1 payload separation.
- EO-1 control of ADCS activation, Solar Array (SA) deployment, and transmitter turn-on.
- Initial EO-1 real-time telemetry acquisition via omni S-band antennas.
- Establishment of thermal and power balance.
- Initial orbit determination.

- ADCS sensor calibration.
- Spacecraft Frequency drift characterization and initial clock adjustments (TBD).
- Complete functional checkout of spacecraft systems.
- ALI turn-on, functional checkout , and calibration.
- Reaching mission orbit.

4.1.1.3 On-Orbit Mission Operations Phase

This phase is a combination of the two formation flying phases, the early and late. The On-Orbit Mission Operations phase is the primary mission phase and will nominally span one year. The point at which mission operations will transition to this phase is approximately launch +30 days. It is during this phase that science data is collected. Operations success criteria during this phase include the following:

- Achieving mission goals, objectives, and archive refresh requirement.
- Continued safe, productive operations of the satellite.
- Validation of new technology on board.

4.1.1.4 Extended Mission Phase

This phase is the last phase of the mission. At some point a government decision will be made to terminate or extend the mission. For this phase, success criteria is simply the successful execution of continued operations.

4.2 Spacecraft Operations

This section provides information regarding spacecraft subsystem operations, with a special emphasis on those areas requiring real-time monitoring, trending and performance analysis, routine ground intervention, or possibly special interaction in the event of a spacecraft anomaly. The Flight Procedures Document (FPD) will contain much of the detail on the responsibilities and functions mentioned below. It will show the step by step instructions on how to perform the responsibilities needed to be performed to operate the spacecraft and ground system. It will be written in a latter stage of pre mission operations. In addition to all the operations implied within this section, the FOT will be responsible for any and all trending necessary to characterize and sustain the health and continued operations of the spacecraft. The Spacecraft Description and Operations Users' Manual describe the spacecraft subsystems in detail and will also list all spacecraft related constraints and restrictions that the FOT will have to follow during operations.

Housekeeping operations are those done in order to support operations of the spacecraft and facilitate the obtainment of the mission objectives. The MOC and all ground stations support housekeeping operations. These elements are responsible for successfully accomplishing the following tasks;

- Ensure the health and safety (H/S) of the spacecraft.
- Support and conduct safe housekeeping operations of the spacecraft.
- Support and conduct safe payload operations of the spacecraft.
- Plan and schedule ground communications resources.

- Plan, schedule, and manage spacecraft resources.
- Assess the health and performance of the spacecraft.
- Manage the tools and resources of the MOC elements.
- Provide an adequate system to react to anomalous situations in order that above items may be accomplished with minimal interruption.

4.2.1 Command and Data Handling

The Command and Data Handling (C&DH) subsystem is comprised of hardware and software elements performing services of command reception, validation and distribution, telemetry processing, data storage, stored command processing, clock maintenance, and time distribution. Components in the C&DH are listed in Section 3.1.2.4 along with a high level description and figure of the system.

The primary operations during which the ground system will interact with the C&DH subsystem include table and memory operations, stored command processing, and recorder management. Some of the responsibilities of the autonomous MOC system and FOT are listed below. They are separated by subsystem component and are in addition to the normal trending that will be done.

- TBD
 - Configure and manage MOC handling and response to commands rejected by the TBD because of CCSDS error or Spacecraft Command Counter (SCC) mismatch.
- Mongoose V
 - Recognize and react to any autonomous failovers.
 - Maintain non-volatile configuration memory (EEPROM auto-configuration table) on-board the spacecraft and within the ground system.
 - Execute EEPROM write operations in accordance with all established duty cycles and restrictions.
 - Execute all operations necessary after an initialization (TBD).
 - Manage all telemetry contributed to the narrowband telemetry stream by the Mongoose V (TBD). This includes keeping updated ground records of all Mongoose V telemetry configurations and following all established procedures and restrictions.
 - Follow established procedures to manage Command Verification words generated by the Mongoose V. This includes anticipating its reaction to commands that fail validation (for example, how it handles Absolute Time Commands vs. Relative Time Sequence Commands when validation fails).
 - Manage and configure autonomous Error Detection and Correction (EDAC) on-board the spacecraft.
 - Recognize, react to, and report any autonomous spacecraft configuration changes brought about by the EDAC software.
 - Follow established procedures when loading stored commands (command buffer management).
 - Manage Relative Time Command Sequence (RTCS) table. Spacecraft and ground tables must match and be properly tested.
 - Manage Mongoose V RAM and ROM, keeping a ground image of RAM contents on the ground.

- WARP and SSR
 - Reassign the block assignments for data stored on the recorders. This is called the Rename or Re-mapping function and should be done on a daily basis. This is TBD.
 - Perform de-fragmentation on the recorders memory as needed (this ability is TBD).
 - Manage the “Allocate” and “Write Protect” flags (TBD).
 - Execute self-diagnostic software on recorders as necessary.
 - Manage recorders capacity with ground modeling. The FOT must always know the status and configuration of the recorders’ memory.
 - Configure the WARP as necessary to return the needed narrowband telemetry to the ground (switching between available formats, etc.). Also, follow all restrictions and procedures when changing WARP configurations.

4.2.2 Attitude Determination and Control Subsystem

The ADCS provides the spacecraft with the sensors and actuators needed to establish and maintain a safe, stable attitude for payload operations under normal and anomalous conditions. EO-1 has the added responsibility of maintaining a stable location with respect to Landsat 7 (Formation Flying). For a complete listing of components in the ADCS and a high level diagram of the system, see Section 3.1.2.5. In the following sections, operational considerations of some of the ADCS components are discussed. Although much of the attitude control functions on the spacecraft are automated and require little if any ground intervention, trending will be done in order to assess the subsystem and component performance. Also, the Formation Flying experiment will require ground calculation of maneuvers. Some of the responsibilities of the MOC system and FOT are listed below. They are separated by subsystem component and are in addition to the normal trending that will be done.

The reaction control subsystem is part of the ADCS. The reaction control subsystem will perform orbit maintenance maneuvers and Formation Flying maneuvers. Catalyst bed heaters will be controlled from the ground and it is essential that they be on (and the catbeds reach a set, minimum temperature) prior to any thruster use. Nominally, both primary and redundant heaters will be used so if one fails while out of ground contact, the thrusters will remain warm. In addition, there will be survival heaters in the subsystem to keep all “wet” areas at acceptable temperatures. These heaters remain ON at all times. Latch valves within the system may be closed only through ground command, but once on-orbit they will not be cycled under nominal operations and will be left in the OPEN position.

- Gyros
 - Track and characterize gyro drift (calculated by TBD).
- Reaction Wheels, Three Axis Magnetometer, RCS
 - Manage system to avoid any of the wheels from passing through zero RPM during normal operations. TBD.
 - Configure system to be consistent with established operating procedures (nominally disable automatic switching to thruster momentum unloading, for example).
 - Reaction wheel speeds are to be managed to maintain spacecraft stability during imaging.
 - Trending of the reaction control subsystem will include the following:

- Tank pressure and temperature.
- Thruster performance (includes maneuver performance assessments, and trending and analysis of catbed and valve temperatures during thruster use).
- Amount of N_2H_4 left in tank.
- Number of times latch valves have been cycled (will also be logged prior to launch).
- Total number of pulses fired for each thruster.
- Catbed heater cycles.
- General ADCS
 - Manage the smooth transition to and from those ADCS modes which require ground intervention to be switched.
 - Follow all established procedures and restrictions when performing maneuvers.
 - Ensure that at no time are any attitude position or rate limits exceeded for the current ADCS mode. If limits are exceeded, action must be taken to ensure spacecraft safety.
 - Establish and follow all necessary contingency procedures.
- Formation Flying
 - Obtain ephemeris from Landsat 7 and EO-1 orbit data, and use to calculate maneuvers.
 - Run the Autocon program to perform FDS functions related to formation flying.

A timeline of events which happens on board the spacecraft during a typical maneuver can be seen in Figure 4-3.

Time Elapsed	Duration	Event
00:00:00	18 minutes	Spacecraft in earth pointing mode
00:00:00	1 second	Stored command to begin maneuver sequence activated
00:00:01	40 minutes	Enable engine valve driver and catbed heater
00:02:00	40 minutes	Quick look attitude verification
00:09:00	40 minutes	Record health and safety at 12 Kbps
00:12:00	30 minutes	Solar array at index
00:18:00	1 minute	Start maneuver sequence
00:19:00	3 minutes	Slew
00:23:00	7 minutes	EP with offset (ADCS)
00:24:00	11 minutes	Enable TSM and backup timers
00:25:00	20 minutes	Arm thruster
00:29:00	3 minutes	Burn - fire thruster
00:32:00	5 minutes	EP with offset
00:33:00	3 minutes	Rate null
00:37:00	4 minutes	Slew
00:41:00	Continuous	Earth pointing attitude
00:48:00	Continuous	Record health and safety at 2 Kbps

Figure 4-3. Timeline of Events During Typical Spacecraft Maneuver

After the data from the maneuver sequence is dumped to the ground, the FOT will verify the tank pressure to make sure it conforms with the expected value.

4.2.3 Electrical Power Subsystem

Aside from trending of solar array, battery, and general subsystem performance, there will be few routine operations associated with the EPS during nominal On-Orbit operations. There will be some activities (setting of some FSW parameters) required of the FOT during ascent and after any Mongoose V resets. Contingency operations will be developed for anomalous solar array deployment, low power situations, autonomous load shedding recovery, and there may be some operations that involve commanding the array during initial orbit and early orbit checkout period.

During normal operations there will be few operations associated with the batteries. The Battery Charge Regulator (BCR) has eight voltage/temperature (V/T) levels and four current levels which can be selected by the FSW or the FOT to tailor the charge and voltage state of the battery. Nominally, these V/T and charge current levels will be autonomously selected by the FSW, and selection by the FOT will occur only during special or contingency operations. Battery reconditioning may be needed, but is not planned for the one year mission.

A power balance model will be used by the FOT as a tool in assessing and predicting performance of the EPS.

4.2.4 Communications Subsystem

The Communications subsystem provides the interface between the EO-1 spacecraft and the ground. This subsystem will provide forward and return link communications services for telemetry, command, and tracking operations. A block diagram of the EO-1 Communication subsystem is shown in Figure 3-8. Some of the responsibilities of the MOC system and FOT are listed below. They are separated by communication band and are in addition to the normal trending that will be done to assess subsystem performance.

- S Band
 - Perform Housekeeping telemetry playback.
 - The proper S-band mode (coherent vs. non-coherent, etc.) must be selected prior to each contact and will be built into the stored command load by the scheduler. These settings may be changed by the FOT or MOC during the pass. This is TBD.
 - The FOT must establish and follow guidelines/procedures to operate the S-band system when it switches to its “AUTO-ON” mode during spacecraft contingency operations. It is very important that the FOT fully understand this mode and the operations associated with it. Specific procedures will be developed that address operations of the S-band system in the Auto-On mode. This is TBD.
- X Band
 - Perform science data telemetry playback.
 - The X band antenna must be calibrated on a periodic basis (TBD).
 - Configuration of the X-band system must be maintained following established guidelines.

4.2.5 Thermal Control Subsystem

Thermal control subsystem operations are very limited. Trending and characterization of the spacecraft thermal behavior throughout the orbit will be a prime effort of thermal control subsystem operations.

4.2.6 ALI Operations

There will be little or no real-time operations of the ALI, nearly everything done with the instrument during normal operations will be accomplished via stored commands (either supplied via command loads or by on board command sequences). Some of the responsibilities (in addition to trending activities) of the MOC system and FOT are listed below.

- Scheduling of all ALI imaging will be done by the MOC/FOT.
- When scheduling ALI operations, its duty cycle, and power draw on the bus will be tracked to ensure no limits are violated.
- When scheduling a scene for imaging, ALI gain settings will be included.
- Calibration operations (Solar Calibration and Lunar Calibration) of the ALI will be scheduled and executed. SDC will provide the FOT with days and/or orbits when the calibrations are to take place. Established calibration procedures for the instrument will be agreed upon by the SDC, FOT, and ALI subsystem engineers. Figure 4-4 shows the calibration pipeline software flow diagram.
- Other calibration operations (ground truth images for example) will be coordinated between the FOT and SDC personnel.
- Ensure proper and safe ALI configuration during any and all contingency operations.
- Instrument alignment.

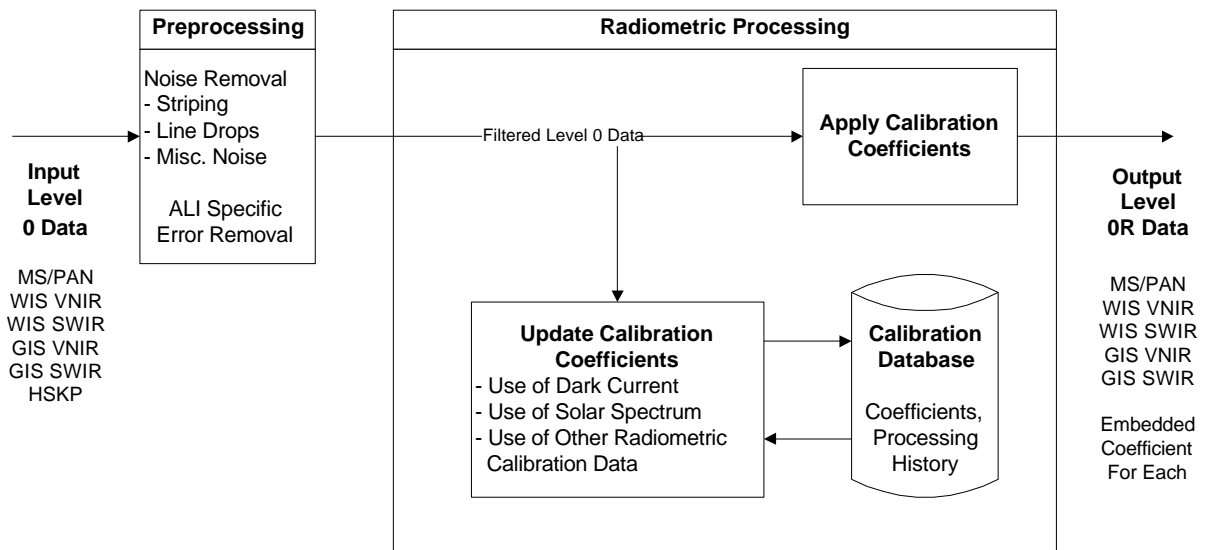


Figure 4-4. Calibration Pipeline Software Flow Diagram

4.3 Commanding and Real Time Operations

This section provides a brief overview of nominal real-time activities that will take place. All real-time telemetry and command operations will be conducted from the MOC at GSFC. Real-time operations will consist of real-time telemetry processing, command up-link and verification, recorder management, and table and memory load/dump operations. The ground station will be responsible for ensuring that it is capable of supporting the requested command and telemetry operations. All commands will be up-linked in real-time through the station and all real time telemetry received will be forwarded to the MOC in real-time as well as being captured. The X band WARP data is recorded to tape and mailed to the MOC within 48 hours.

It is envisioned that 2 contacts each day will be necessary for real-time operations. Each of these will be used for real-time housekeeping telemetry collection, playback housekeeping data collection, and payload playback data operations.

Under normal conditions, all commanding and real time capture operations are performed based on predetermined schedules. The stored command uploads and recorded real time data recovery will be performed through the ground stations. All communications resources are pre-scheduled. The ground station will perform in the “bent-pipe” mode for both up-links and down-links. In down-links, they will receive real time data channels and retransmit the stream to the MOC via available communications links without any delay.

For up-links, the Ground station transmit antennas are slaved to the receive antennas. The MOC will wait until confirmation from real-time telemetry from the ground station that test commands have been received by the spacecraft before initiating any up-link tables. Command uploads include:

- Stored command tables.
- Landsat-7 state vectors.
- Clock resets.
- Onboard software patches and table loads.

Real-time commanding is not baselined but will probably be required periodically throughout the mission. Real-time commanding may be used to initiate commanding of the housekeeping data recorder to playback telemetry data to the ground. The MOC and satellite have the capability in real time for direct commanding, as well as two-step commands (transmit, verify, execute).

As all tracking events and passes use limited, shared resources, all normal contacts are pre-scheduled. Therefore, the MOC operates from a daily schedule that is used to activate pass/contact preparation. Part of the preparation of the ground station is to pre-compute the vectors to the satellite for the pass so that the station’s directional antenna can be pointed at the satellite throughout the pass, regardless of the presence of signals. This mode of operation is called “program track.” Because the spacecraft is operating from stored command loads, it begins preparation for the pass before the ground station is at the spacecraft horizon. This includes setting up the transponder to broadcast real-time telemetry.

When the signal is detected at the ground station, the receive antenna switches into autotrack mode, in which it automatically points in the direction of the strongest signal, and the transmit antenna is slaved to the receive antenna. The recovered telemetry is sent directly to the MOC. The MOC monitors the pass using the real-time telemetry. The telemetry data are also archived and used for other FOT activities. Ground station status is sent directly to the MOC, which also monitors ground station equipment status during the pass.

Figure 4-5 shows the stations to be used to conduct real time contacts.

Station	Purpose	Band @ Rate
Spitzbergen	<ul style="list-style-type: none"> • up-link of stored cmd/memory loads • up-link of real-time cmds • down-link of recorded H/K tlm • down-link of real-time H/K tlm • down-link of stored payload data • backup down-link of stored payload data 	<ul style="list-style-type: none"> • omni S-band @ 2 Kbps • omni S-band @ 2 Kbps • omni S-band @ 1 Mbps • omni S-band @ 32 Kbps • electronically gimbaled X-band @ 105 Mbps • omni S-band @ 4 Mbps
WFF	<ul style="list-style-type: none"> • up-link of stored cmd/memory loads • up-link of real-time cmds • down-link of recorded H/K tlm • down-link of real-time H/K tlm • down-link of stored payload data • backup down-link of stored payload data 	<ul style="list-style-type: none"> • omni S-band @ 2 Kbps • omni S-band @ 2 Kbps • omni S-band @ 1 Mbps • omni S-band @ 32 Kbps • electronically gimbaled X-band @ 105 Mbps • omni S-band @ 4 Mbps
Poker Flats	<ul style="list-style-type: none"> • up-link of stored cmd/memory loads • up-link of real-time cmds • down-link of recorded H/K tlm • down-link of real-time H/K tlm • down-link of stored payload data • backup down-link of stored payload data 	<ul style="list-style-type: none"> • omni S-band @ 2 Kbps • omni S-band @ 2 Kbps • omni S-band @ 1 Mbps • omni S-band @ 32 Kbps • electronically gimbaled X-band @ 105 Mbps • omni S-band @ 4 Mbps
McMurdo	<ul style="list-style-type: none"> • up-link of stored cmd/memory loads • up-link of real-time cmds • down-link of recorded H/K tlm • down-link of real-time H/K tlm • down-link of stored payload data • backup down-link of stored payload data 	<ul style="list-style-type: none"> • omni S-band @ 2 Kbps • omni S-band @ 2 Kbps • omni S-band @ 1 Mbps • omni S-band @ 32 Kbps • electronically gimbaled X-band @ 105 Mbps • omni S-band @ 4 Mbps
TDRSS	<ul style="list-style-type: none"> • down-link of real-time H/K tlm during launch 	<ul style="list-style-type: none"> • omni S-band @ 2 Kbps

Figure 4-5. EO-1 Space - Ground Communications Summary

4.3.1 Telemetry Handling and Monitoring

Housekeeping data will arrive in the MOC in the form of real-time telemetry and stored telemetry playbacks. Real-time telemetry will be used to assess the health and safety of the spacecraft, help ensure that onboard operations are proceeding as planned, and confirm the execution of real-time commands. Real-time telemetry down-link will be scheduled during all confirmed communication contacts. Housekeeping playback data will be captured on disk at the ground station and processed in an off-line manner. Dumps of stored housekeeping data will be scheduled to occur during each contact. Real-time and playback housekeeping data may be down-linked

simultaneously and will be broken up with real time data sent to the MOC in real-time by the receiving station and playback sent by mail on tapes. The receiving stations will capture the data, store it for a specified amount of time, and make it available for the FOT to replay to the MOC in the event of a communication problem between the MOC and station during the contact.

Both real-time and recorded telemetry will be ingested by the MOC. Real-time telemetry is used to ensure the health and safety of the spacecraft and payload and will be down-linked during all scheduled passes. Recorded housekeeping data will be dumped each pass and will be used for trending and subsystem performance analysis as well as anomaly recognition. The processing of real-time and recorded telemetry is identical, although certain features of the system may be disabled while processing recorded data in order to speed up the process. All real time data will be captured at the ground sites and simultaneously sent to the MOC in real-time. Functions and responsibilities of the MOC/FOT in the area of telemetry handling and monitoring are shown below. Details of these functions, and the tools used to perform them will be contained in the FPD.

- Telemetry capture and decommutation.
- Telemetry, planning aid, and database display on color displays. These displays are provided by the RTS system, FOT, and TBD.
- Real-time telemetry will be continuously monitored by the MOC by the Asist software for anomalous conditions. Playback data will also be scanned for anomalous conditions.
- Telemetry data subset collection will be performed to support FDS functions.
- Special processing and equation processors will be enabled as needed. Equations may be supplied by the spacecraft builder and/or FOT.
- Subset generation of related telemetry points from playback data is done to facilitate later trending, reporting, image calibration, subsystem/component performance assessment, and anomaly resolution.
- Hardcopy reports may be generated on telemetry statistics, telemetry values, trending results, event reports, limit violations, FSW contents, etc.
- Memory/table dump collection and comparison to GRI files.
- Data accounting/archival.

Telemetry will be decommutated and displayed on the MOC screens in display pages designed by the RTS developers and the FOT. The telemetry will be color coded and checked against limits contained in the Operational Database (ODB). Each telemetry point will have specific limits associated with it and these limits can be adjusted or disabled by an FOT member with appropriate access privileges. The limit checking function of the RTS will change the color associated with any telemetry point that reaches defined limit boundaries. Telemetry monitoring and interpretation is an intensive task, and will take much time. Scripts and special procedures will be written to lessen this task.

4.3.2 Command Operations

A command link will be scheduled whenever real-time support is scheduled. Commands can be up-linked to the spacecraft in real-time or as part of a memory or table load. Commands sent from the MOC will nominally include real-time commands to control data playback, stored

command loads and ephemeris loads. There will be one stored command load up-linked approximately every 72 hours and every load will contain stored commands covering 1 week of operations. 72 hour ephemeris loads will be up-linked 3 times per week. The ephemeris file is perishable and should be up-linked at the first available opportunity after the file is created. Commands will be generated by the MOC software at FOT request and sent to the appropriate ground station where they will be up-linked to the spacecraft in real-time. Command loads will be up-linked to a scratch buffer in the Mongoose V where a checksum is performed prior to being transferred to the working buffer and activated. During the transfer between buffers, stored command processing must be disabled. Because of this, Ephemeris and stored command loads must be activated onboard the spacecraft during times when no stored commanding is scheduled. In addition, Ephemeris loads should not be activated while the ALI is imaging.

Groups of spacecraft commands, EGS directives, or Asist directives that accomplish a specific task may be grouped together in command procedures (procs) that have been pre-built and tested by the FOT. These procs reside within the RTS/Asist environment and not only lighten the workload of the FOT, but also ensure a standard, tested sequence of commands is always used for a given situation. Nearly all commands sent to the spacecraft, and many of the directives used to control RTS/Asist will be executed via procs. Responsibilities of the MOC/FOT during all commanding operations are listed below.

- Format and validate all commands sent according to the Operational Database (ODB). Any raw commands sent by the FOT or MOC (infrequent if ever) will not be validated.
- Configure the commanding system according to established guidelines. This includes setting the following parameters:
 - One or two step (default) commanding.
 - Command receipt verification enabled (default) or disabled.
 - Wait for real-time command receipt verification enabled or disabled (default).
 - End-item verification enabled (default) or disabled.
 - Automatic retransmission enabled (default) or disabled.
- Require operator confirmation of all critical commands.
- Provide command rate metering.
- Provide the capability to have several validated stored command loads ready for up-link.
- Provide the means to detect and react to commands or command loads that are not accepted by the spacecraft for any reason.
- Provide security to ensure only one FOT member may command at a given time.
- Ensure that any commanding done will not violate constraints or restrictions set forth in the On-Orbit Handbook or other operational documentation

4.3.3 Real Time Event Scenarios

Most operations with the ground station will take place within an acquisition circle defined by a 45° cone (TBD) around the EO-1 zenith. This “constrained geometry” is a result of the RF design. The nominal service requested from the ground station contacts is for the 11 meter automated antenna. Nominal events within the constrained geometry will be approximately 10-15 minutes in duration, with a forward link throughout, and in coherent mode. Two passes are

needed each day to collect sufficient WARP data. Figure 4-6 shows a typical science pass from the spacecraft's point of view.

Time Elapsed	Duration	Event
00:00:00	Continuous	Mission telemetry, record at 2 Kbps
00:05:00	1 second	Stored command to begin scene taking sequence activated
00:05:01	25 minutes	Engineering telemetry, record at 12 Kbps
00:12:00	10 minutes	Stop solar array
00:12:00	10 minutes	Open aperture door
00:20:00	26 seconds	Acquire image
00:20:00	27 seconds	WARP record image
00:20:26	1 second	Dark image
00:30:00	Continuous	Mission telemetry, record at 2 Kbps
00:35:00	1 second	Stored command to begin pass sequence
00:40:00	10 minutes	Real time pass
00:40:00	10 minutes	Acquire Spitzbergen X band down-link at 105 Mbps
00:40:00	10 minutes	Acquire Spitzbergen S band down-link at 2 Mbps
00:40:00	10 minutes	EO-1 housekeeping playback
00:40:00	3 minutes	EO-1 command activities
00:40:00	4 minutes	EO-1 WARP playback
00:43:00	4 minutes	EO-1 quick-look verification
00:50:00	1 second	Transmitter off

Figure 4-6. Typical Science Pass

The following sections give high level descriptions of real time pass scenarios.

4.3.4 Pre Pass Operations

The following is a high level description of pre pass operations.

- Initialize all MOC equipment needed for real-time operations (this activity may be needed only once per day).
- Perform readiness/configuration check and run set-up procedures on all hardware and software (set-up procedure may exist as a predefined command/directive procedure).
- Ensure that station hardware/software and all data lines are ready. This may include sending a test command to the station to confirm command path.
- Ensure there is time built into set-up schedule to handle any configuration problem prior to AOS.

4.3.5 Pass Operations

The following is a high level description of pass operations.

- Confirm the spacecraft state of health.
- Perform all scheduled commanding and telemetry operations detailed in pass plan. This may include dumping and collecting stored narrowband data, initiating Doppler data collection, up-linking of stored command loads, etc.

4.3.6 Post Pass Operations

The following is a high level description of post pass operations.

- Perform “clean up” operations as needed. This may include closing out and archiving files, filing electronic reports to supporting elements, etc.
- Begin processing and evaluation of collected dump data if appropriate.

4.4 Off-line Operations

Off-line operations consist of the planning and scheduling function, engineering and maintenance operations (maneuver planning, spacecraft clock calibration, etc.), performance and trend analysis, software and database management, narrowband data archive, and sustaining engineering efforts. Off-line operations that support payload activities consist of processing, reprocessing, archiving, and assessment of image data. Other Off-line activities consist of management functions, hardware and software maintenance, anomaly investigation, and report generation.

4.4.1 Long Term Planning for Payload Operations

The planning and scheduling for EO-1 is broken down into two categories: Long Term Planning and Short Term Planning, which includes Daily Planning and Scheduling. The activities that take place during these three phases are shown in Figure 4-7. The end product of this process is a constraint free, safe command load capable of running spacecraft operations for 7 days.

The long term planning process begins prior to launch with the generation of the Long Term Plan, Operational and Project Databases, and the initial build of a Ground Reference Image of all flight software. These three products form the foundation that will be used in all subsequent planning operations. They are essential for the completion of the planning and scheduling process which culminates in conflict free command loads.

The long-term planning scenarios include the buildup of necessary MOC scheduling databases prior to launch and the periodic change of imaging strategy initiated by the NMP EO-1 Science Working Group (SWG) once normal on-orbit operations are underway. The pre-launch activities are discussed in Section 5.

The NMP EO-1 SWG selects NMP EO-1 science targets in conjunction with the Landsat-7 SWG. A prioritized target list is provided to the EO-1 MOC planning and scheduling system. This comprehensive database contains at least one request for every scene that is required to be imaged in the new long-term plan.

The MOC planning system checks and validates the long-term database before converting it to operational status. Once validated, the request scheduling database is built by the MOC from the long-term database. The request scheduling database is the database used by the MOC for all daily scheduling operations. Although not used for daily operations, the long-term planning database is retained by the MOC off-line for archival or updating under direction of the NMP EO-1 SWG.

Long Term Planning

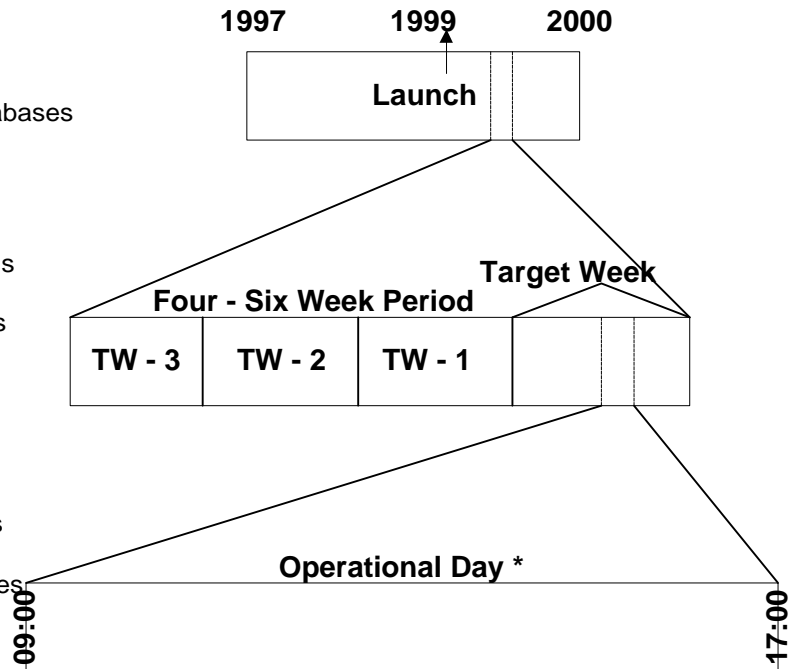
- Create Long Term Plan
- Create Operational and Project Databases
- Update These Products As Needed

Short Term Planning

- Receive/Generate FDS Planning Aids
- Submit Communication Requests
- Receive Communications Schedules
- Receive/Process Imaging Requests
- Create Initial Command Lists

Daily Planning and Scheduling

- Receive/Process Imaging Requests
- Receive/Process Tracking Data
- Run Scheduler for Candidate Scenes
- Generate Command Loads
- Generate Reports



* **Note:** The operational days for mission planning on EO-1 are Monday through Friday.

Figure 4-7. EO-1 Planning and Scheduling Concept

Changes to the long-term plan may either be accomplished directly by the NMP EO-1 SWG or by the MOC under guidelines from the SWG.

4.4.2 Short Term and Daily Planning for Spacecraft and Payload Operations

There are two major activities associated with the short-term planning for NMP EO-1. The planning of communications contacts will usually be performed several weeks in advance because the communications resources are extremely limited and must be shared with a number of missions. The actual scheduling of satellite activities, including which scenes are imaged, is conducted for a 48-hour period, except on weekends, where scheduling may need to be performed for up to 96 hours.

The communications planning activities are based on a weekly update of the contact schedules for an activity period several weeks in advance.

The daily scheduling of the imaging and SSR utilization begins at least 6 hours prior to the start of the contact at the ground station that will be used to up-link the satellite's command load. This process generates a 48-hour or 96-hour conflict-free stored command list for both the spacecraft bus and the ALI activities.

Data required for the scheduling process include:

- Ground station contacts for the period.

- Information on which orbits (with their associated scenes) will be covered during this period (usually expressed as nodal crossing times).
- Planned time to upload the command tables, Landsat 7 state vectors, and memory loads.
- Spacecraft maintenance activities such as maneuvers or changes in power utilization.
- Instrument calibration requirements.
- Scene request scheduling database that contains the requests for imaging.
- Special requests, as approved by the NMP EO-1 SWG.

Once the MOC operator has selected the scheduling timeframes, the scheduler software will ingest the above input. The scheduler software will then use the nodal crossing times to calculate the paths and rows for the scheduling period and extract from the request scheduling database the list of candidate requests for all the scenes that the spacecraft will fly over for the selected scheduling period.

The scheduler software will use the historical database to determine the status of all candidate scene requests. If the historical database indicates that the candidate scene request has already been satisfied (i.e., the scene has been successfully refreshed at the rate specified in the request and the scene passed quality checks), the scene will not be scheduled in this scheduling period. Each candidate scene request has associated with it a minimum acceptable Sun angle value. This value indicates what level of Sun angle is acceptable to schedule the scene. The scheduler software will compare the candidate scene request Sun angle parameter against the known Sun angle (based on FDS calculations). All candidate scene requests that fail this criterion will not be scheduled in this scheduling period.

The scheduler software will then use the knowledge of the known spacecraft maintenance activity times to eliminate other candidate scene requests. All requests that fall within any of these planned activity times will not be scheduled in this scheduling period.

The scheduler software will then prioritize each of the remaining requests. Utilizing the continuity models (SSR and ALI) from the previous scheduling run, the scheduler software will attempt to schedule the remaining scenes for ALI imaging, SSR playback/record operations, as well as real-time down-links to the MOC.

If the schedule has conflicts (i.e., SSR capacity is overloaded), the lowest priority scenes will be eliminated by the scheduler software. The remaining scenes are then rescheduled. This process is continued iteratively until a conflict-free schedule is produced. If the scheduler software cannot arrive at a conflict-free schedule, operator intervention will be requested.

Each activity from the conflict free schedule will have a power consumption requirement value associated with it, and the scheduler software will total the requirements and compare that answer with the available power on each orbit. If the power requirements exceed available power, the scheduler software will indicate operator intervention will be required.

The scheduler software will have access to the ALI instrument duty cycle limits. Scheduled ALI on/off cycles will be monitored by the scheduler software, and a duty cycle check of ALI on time will be calculated.

The final output of the scheduler software is a time-ordered stored command list for both the spacecraft bus and payload stored command tables. The stored command lists produced by the scheduler will contain the following time-ordered activities, covering up to a 96-hour period:

- Operations for the ALI instrument (including on, off, gain changes, mode changes and calibrations).
- Operations for the SSR (including record, playback, rename, allocate, write-protect, and de-allocate).
- Communications (both X-band and S-band initiation and termination and frequency assignments).

In addition to the stored command lists, the scheduler software will provide various reports for the FOT on the results of the scheduling process. Included as one of these reports is a daily request scheduling report that shows each potential request and the status of whether it was scheduled or not. If the request was not scheduled, an explanation of why the scene was not scheduled will be included in the report.

The stored command lists will then be made available to the load generation function to convert the time-ordered stored command lists into time-tagged spacecraft command loads to be uplinked to the spacecraft.

The following sections provide details into specific aspects of short term and daily planning.

4.4.2.1 FDS Planning Aids

Several files containing FDS planning aids will be needed by the FOT and the scheduler and will be generated in the short term planning phase. Sun angle, station contact times, shadow entry/exit time are examples of these files. A detailed listing of the needed products will be given in the EO-1 to FDS ICD. Many of these planning aids will be generated by the FOT using FDS provided software (TBD) which will reside in the MOC on an FDS workstation, which may be shared with other functions. The FDS must also have a PC with Windows NT.

4.4.2.2 Ground Site Scheduling

The ground station contacts will be scheduled through WOTIS (TBD). The FOT will place a standing order of contact requests (or contact requirements) with WOTIS that must be fulfilled each day. WOTIS will send a strawman contact schedule covering one week to the MOC three weeks prior to the target week. A confirmed schedule will be sent to the MOC one week prior to the target week. This confirmed schedule will then be used by the scheduling software when building the daily command load. The current concept is to schedule 2 passes each day at Spitzbergen.

4.4.2.3 TDRSS Scheduling for L&EO

The TDRSS network will be used for telemetry monitoring only during L&EO. The TDRSS network is scheduled by submitting requests to the NCC scheduling facility. In the EO-1 mission timeframe, it may be possible for the FOT to define a standing order schedule request at the NCC.

This would allow the FOT to specify certain guidelines (number of contacts, minimum duration, geographical coverage, etc.) for NCC to use when scheduling EO-1 for TDRS support and would eliminate the necessity for the FOT to routinely generate schedule requests. If this option is not available to the FOT, they will interface to the NCC via the User Planning System (UPS). In this case, the scheduling process for EO-1 will be similar to that of other missions using the SN during this time. The process begins three weeks prior to the target week and continues through a week of conflict resolution. The final contact schedule is released one week prior to the target week.

The FOT will negotiate configuration codes with the NCC pre-launch to be used in the scheduling process. Configuration codes are a standard interface tool used between the FOT and NCC to specify the characteristics of a planned TDRSS support. These codes provide specific information on the telecommunications link including carrier frequency, data rates, and other interface requirements for any TDRSS support request.

4.4.2.4 Imaging Requests

Requests for imaging will enter the MOC in a number of different ways. The long term plan, project inputs, and SDC inputs will be the largest sources of imaging requests.

4.4.2.5 Engineering Operations

Engineering operations will be coordinated, planned, and executed by the FOT. Inputs from the SDC, the project, component engineers, and documentation will be used. Some examples of engineering operations are orbit maintenance, spacecraft clock maintenance, star catalogue update, FSW updates, etc. Accepted procedures for all expected engineering operations will be established pre-launch and be adjusted post-launch using on-orbit data and experience. These operations are discussed in Section 4.4.4.

4.4.2.6 Initial Command List

Given the inputs gathered up to this point (Special Requests and Engineering plans particularly) it will be possible for the FOT to begin the process of building an activity list for a particular 7 day period well in advance of that period. This preliminary command list will be used as an input to the scheduling software.

A graphical representation of the daily planning process can be seen in Figure 4-8.

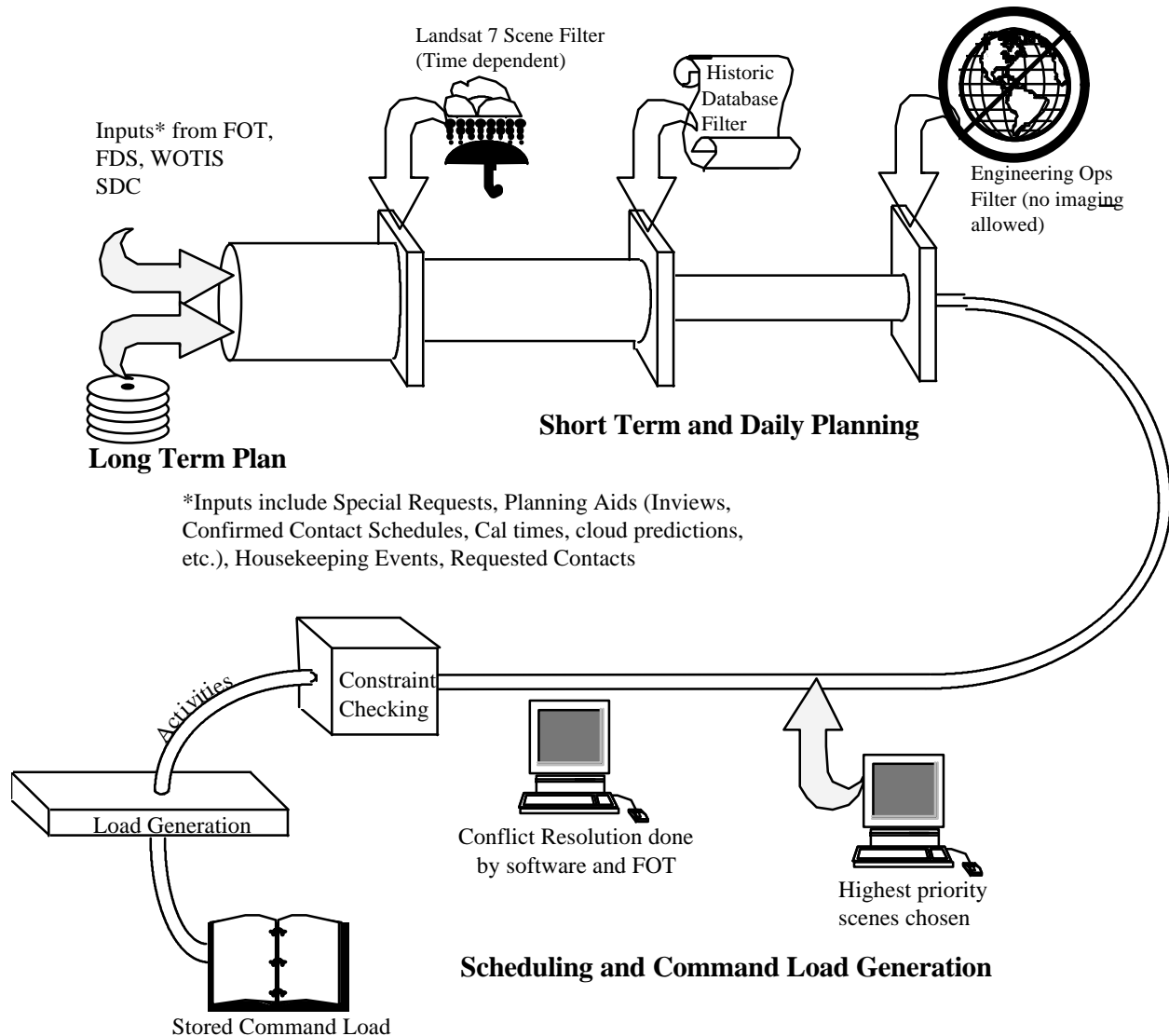


Figure 4-8. Daily Scheduling Pipeline

4.4.3 Off-line Data Processing

Housekeeping data stored on the spacecraft and played back to the MOC will be processed as soon as received from the ground station and will be used for trending, anomaly investigation, subsystem performance analysis, and spacecraft health and safety analysis. For processing, the playback data will be passed through the real-time system at a minimum of eight times the real-time rate (TBD). Playback data will be subsetted into files of related data parameters that will be used for various engineering and payload data processing functions.

Payload data reaching the LZP will be processed as an off-line activity. Payload data will reach LZP via a data tape playback. The ground station will capture payload data on tape and send it to the MOC where it will be played back into the system. The output of this process will be level 0

products and associated metadata and browse files which are then ingested by SDC for level 1 processing. The LZP is capable of processing an average of TBD ALI scenes each day. The payload data processing data flow is shown in Figure 4-9.

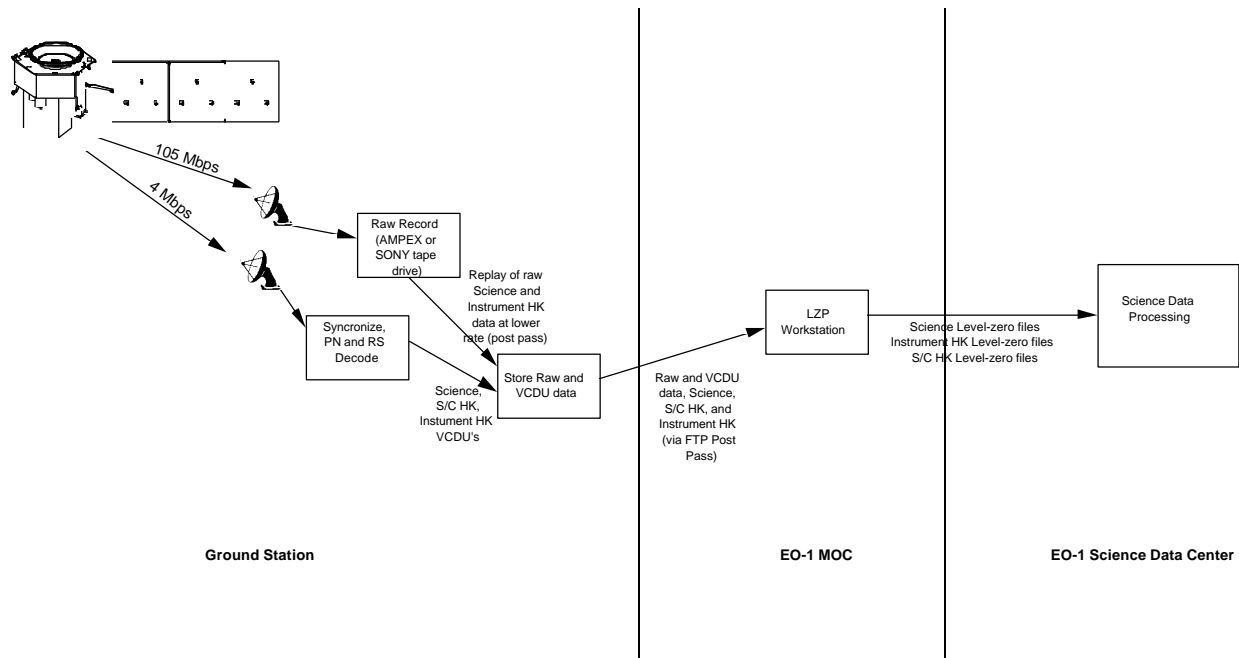


Figure 4-9. Payload Data Processing

It is important for the FOT to constantly know the state of health of all spacecraft subsystems and components and be aware of any trends in performance so that potential problems or concerns may be addressed. To accomplish these objectives, the FOT will perform trending on the playback telemetry data. Trending will also be performed on values and parameters not directly contained in spacecraft telemetry. Certain metrics and performance parameters will be used to gauge MOC/FOT performance and other aspects of ground operations.

The FOT will work with the subsystem engineers to develop a list of parameters that will need to be trended, along with certain behaviors that need to be watched for. Trending will begin as soon as the playback data is captured and is accomplished by passing the data through the real-time system and into an off-line trending system.

Parameters will be trended on a periodic basis which may be an orbit, day, week, quarter, year, etc. The FOT will generate, pre-launch, and update as necessary, a listing of all parameters to be trended, the periods at which they need to be trended, and any specific behaviors the chosen parameters may exhibit.

In addition to being trended, the parameters will be analyzed for any signs of non-nominal behavior and for a general look at the subsystems performance. Subsystem engineers on the FOT will be responsible for analyzing the trending output and applying the results as necessary. A report will be generated on a semi-annual (TBD) basis detailing the current performance of the spacecraft, any spacecraft anomalies encountered over the time period and their resolution, and any predictions or suggestions the subsystem engineers may have for future operations.

4.4.4 Engineering/Maintenance Activities

Spacecraft subsystem operations, performance assessment, reporting, and other activities needed to support housekeeping and payload operations will be done in the MOC by the FOT. In addition, software, hardware, and database maintenance will be conducted. FOT personnel will be responsible for running FDS software in the MOC and producing FDS planning aids and products.

Similarly, at the SDC facility, personnel will be responsible for hardware, software, and database maintenance in addition to any other activities that are necessary to support payload data processing and archive.

Engineering operations consist of activities and efforts that take place in order to maintain and manage the spacecraft resources and orbit. A list of these engineering efforts is given below:

- Orbit maintenance (maneuver planning and performance activities).
- Equipment/sensor calibration implementation.
- Software updates to space and ground systems.
- Spacecraft clock maintenance (GMT correlation, reset, leap second).
- Ephemeris generation.
- FDS planning aid generation.
- Subsystem performance assessment and trending.

In some of these cases, the FOT is responsible to implement the output from another element. For example, flight software updates will be provided by the spacecraft contractor and the FOT merely needs to follow a set procedure for implementing the changes.

In addition to the routine engineering responsibilities, Engineering Operations encompasses anomaly investigation and resolution as well as any other sustaining engineering functions.

FOT subsystem engineers will have tools available to them (analytical tools, documentation, knowledge, spacecraft data, etc.) so that they may successfully execute all engineering operations including anomaly investigation and resolution. In addition, the FOT may need to call upon the expertise of outside engineers in some instances for support.

4.4.5 New Technology Validation

TBD

4.4.6 Software and Database Management

All software and databases used in operations are critical for the successful, safe operation of the system and must be maintained and controlled to ensure that they contain the most up to date information and agree in areas where they interface.

4.4.6.1 Flight Software

The initial flight versions of the Flight and Safe-Hold software for EO-1 will be provided by the spacecraft builder and validated pre-launch. The spacecraft contractor will also be providing on-orbit maintenance of the flight software following flight validation. Post-launch configuration control, and validation of any and all updates to the software will also be the responsibility of the spacecraft contractor (SC). For more information on the exchange of data and files between the MOC and the spacecraft contractor see the Spacecraft Contractor to MOC ICD.

The SC will generate any changes to the flight software that are necessary and ensure that the changes produce the desired results without negatively impacting the rest of the software. The changed software is then passed on to the FOT where the FOT/MOC verify the address space, command syntax, number of bytes in the file, and the load checksum.

After the software load has been successfully up-linked to the spacecraft, the Mongoose V contents are dumped and the Ground Reference Image (GRI) is updated. A copy of the dump is sent to the SC.

4.4.6.2 MOC Software

The software for the MOC system will be integrated by the MOC builder and validated pre-launch. The majority of software in the MOC will be provided by the MOC development team. Maintenance responsibilities of the software packages is TBD.

4.4.6.3 Database Maintenance

Initial development of the Project Database (PDB) command and telemetry specifications is accomplished by the spacecraft builder. After launch, maintenance, control, and distribution (the PDB is needed by the MOC) of the PDB will be the responsibility of the FOT. The PDB contains definitions of all spacecraft commands and telemetry parameters that will be needed by the ground system. In addition, the PDB contains information that allows the MOC software to locate each telemetry parameter in the data stream, perform limit checking, and perform end item verification on every real-time command sent to the spacecraft.

The Operational Database (ODB) is compiled from the PDB and is what the MOC system accesses during operations. The EO-1 ODB consists of telemetry and command specifications (parameters, constraints, etc.), NCC message specifications (TBD only if needed for TDRSS ops), and definitions of system tables and flight software. The FOT is responsible for adding information to the PDB as received by the builder. Some of the values that must be added are NCC configuration codes and message specifications.

4.4.6.4 Miscellaneous

Other areas where the FOT will have to provide configuration control are as follows;

- Relative Time Command Sequence Database
- RTS/Asist Command Procedures

4.5 Operational Timelines

Figure 4-10 shows selected activities for EO-1 on a typical day.

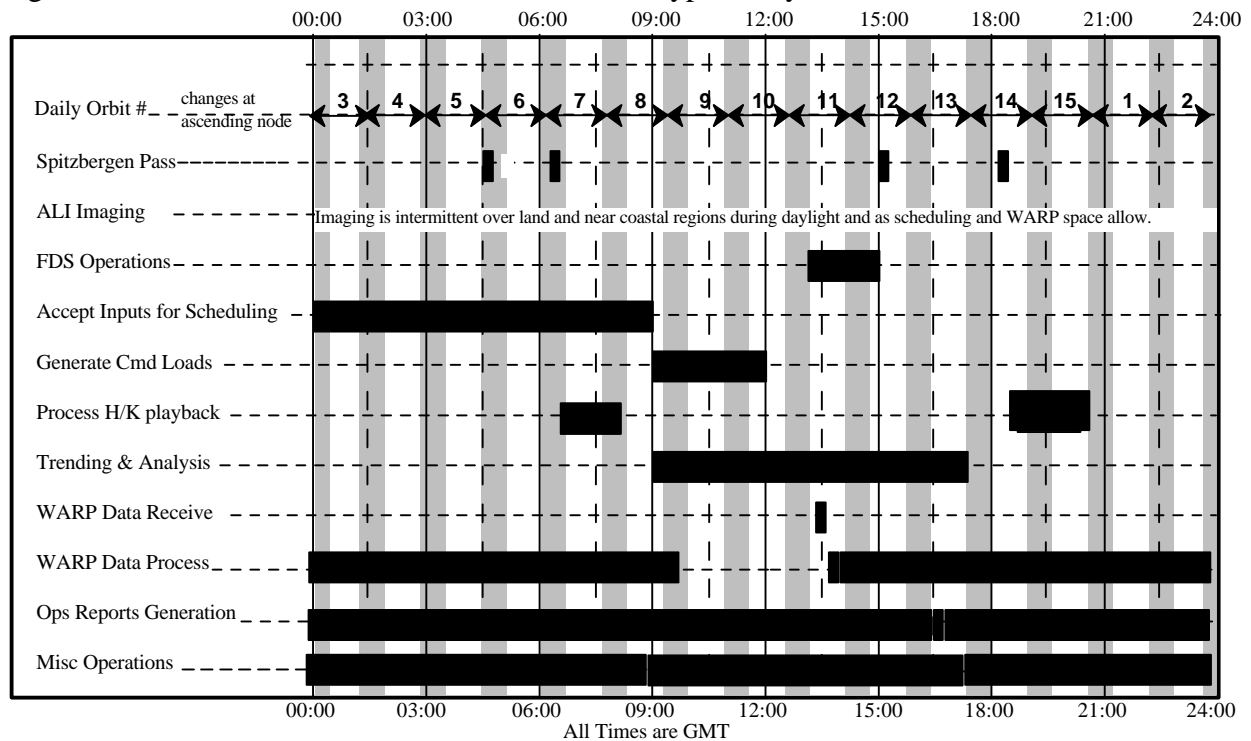


Figure 4-10. 24-Hours of EO-1 Operations

A high level diagram showing the path and timeline of an image from planning to level 1 is shown in Figure 4-11.

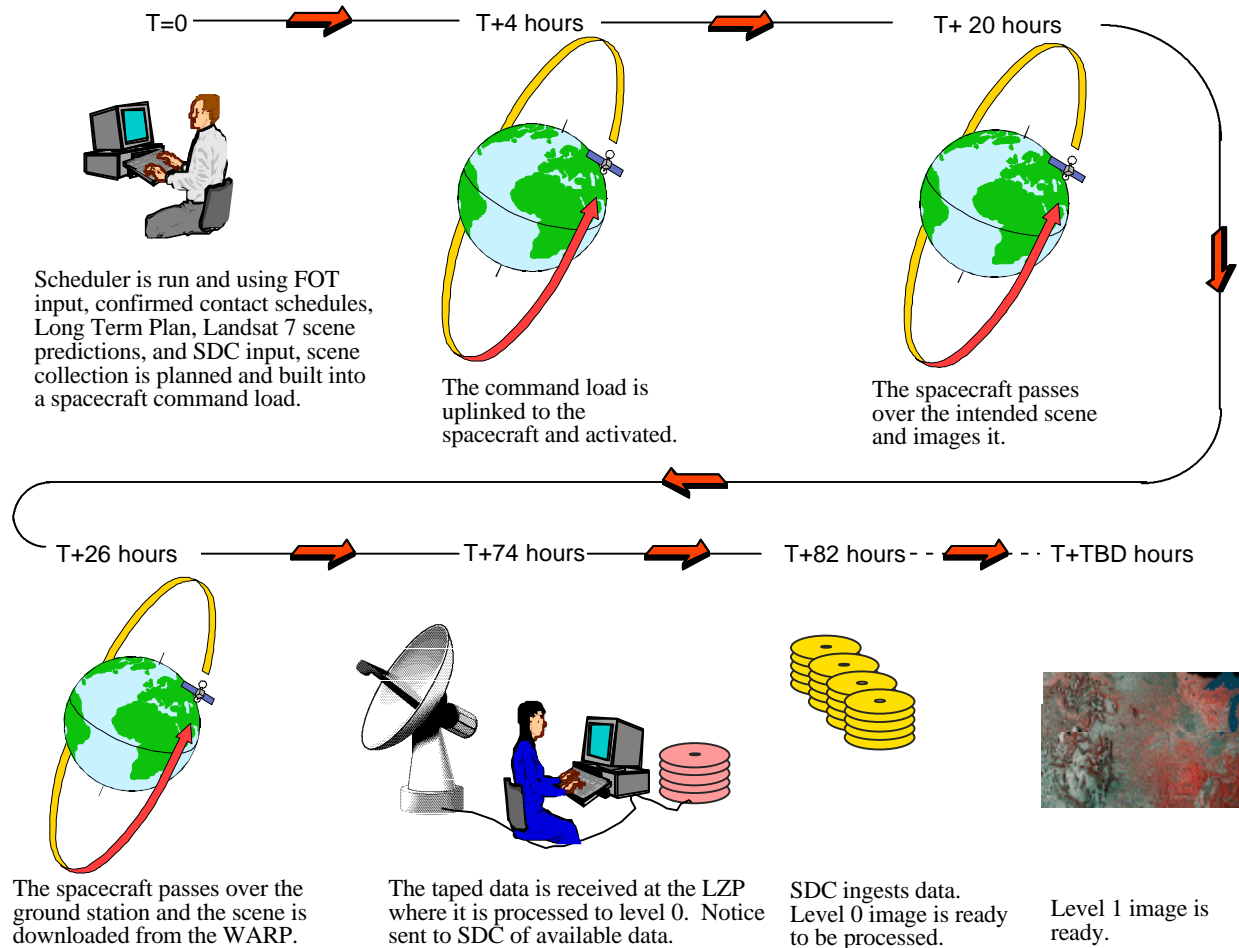


Figure 4-11. Image Product Path and Timeline

4.6 Mission Management

Management responsibility for EO-1 on-orbit operations will be carried out under the same conditions as during pre-launch operations. The project is charged with implementation of the EO-1 Technology Operations Policy. In this capacity, the project will be responsible (through the FOT) for the day-to-day operations of the EO-1 System to fulfill that policy. The FOT will conduct the following activities through project management:

- Plan Mission Operations, to meet Mission Requirements -- This will include all the planning activities leading up to launch, system activation and evaluation, and transition to on-orbit mission operations.
- Manage Data Collection -- This will include developing and maintaining a plan that defines image collection and setting data collection priorities.

A Mission Manager will be responsible for programmatic planning and direction.. The Flight Operations Manager will directly oversee the Flight Operations Team at the Autonomous Mission Operations Center and report on operations to the Mission Manager. The Flight Operations

Manager will also monitor end-to-end performance and oversee Anomaly Resolution, Configuration Management, and systems interface integrity.

4.6.1 Flight Operations Management

The primary job of Flight Operations Management is to establish the procedures, guidelines, and staffing necessary to execute efficient, safe operation of the EO-1 satellite. Oversight of day-to-day Flight Operations will be the responsibility of the Flight Operations Manager. Flight Operations Management activities will include the following:

- Establish standard and contingency operating procedures for flight operations.
- Provide necessary administrative support for flight operations.
- Establish appropriate MOC/FOT staffing levels and shift definition.
- Interface with the Mission Manager, providing support, operational and anomaly reports.
- Maintain all MOC facilities to ensure uninterrupted satellite operations.
- Provide initial and continuing training and certification of all MOC/FOT personnel.

Additional activities will be included as necessary. A detailed description of Flight Operations Management activities will be provided in the Flight Operations Plan.

4.6.2 Transition To On-Orbit Mission Operations

The transition from pre-launch to on-orbit operations will be seamless for EO-1 because the team will not change through these phases.

4.6.3 Anomaly Management

Beginning with end-to-end systems testing during pre-launch, the project, Flight Operations and spacecraft contractor elements will jointly implement a problem management system. This overall system will include a Flight Operations-focused set of anomaly resolution procedures developed by the FOT at GSFC. Problems will be resolved at the lowest possible level. Problems will be documented in databases, and the database will be searchable via the Internet. Contingency plans will be developed for potential failures in each element and each interface. The steps used in the anomaly resolution process are shown in Figure 4-12.

The following list shows the process used:

- When a problem happens, it is isolated to either the Spacecraft/MOC or supporting systems.
- The FOT will identify, as best possible, the problem, notify the Mission Manager, initiate a Problem Report, and execute Contingency Plan, if appropriate.
- The Mission Manager will review initial evidence, assign an Investigator / Analyst, and elevate attention to the problem, if necessary.
- The Investigator / Analyst will review the evidence, get more evidence if necessary, and record in the Problem Database.

- The Originator / Manager / Investigator then defines the desired outcome, which may include eliminating the problem, resuming normal operations, and / or defining appropriate metrics to measure a successful solution.
- The Investigator identifies root cause(s) and proposes solution(s) for a system, equipment and / or, procedures.
- The Flight Operations Manager prioritizes, plans, and tests proposed solution(s), which may be temporary and/or permanent.
- The affected team will refine and implement solution(s), which may include Equipment change, Software update(s), Procedure change(s), and convening the appropriate CCB if required.
- The Flight Operations Manager will measure progress and hold any gains by, for example, trending appropriate monitor points.
- Finally, the result is recorded and communicated to the Mission Manager. In doing so, the Problem Report is finalized, and logged into Problem Database.

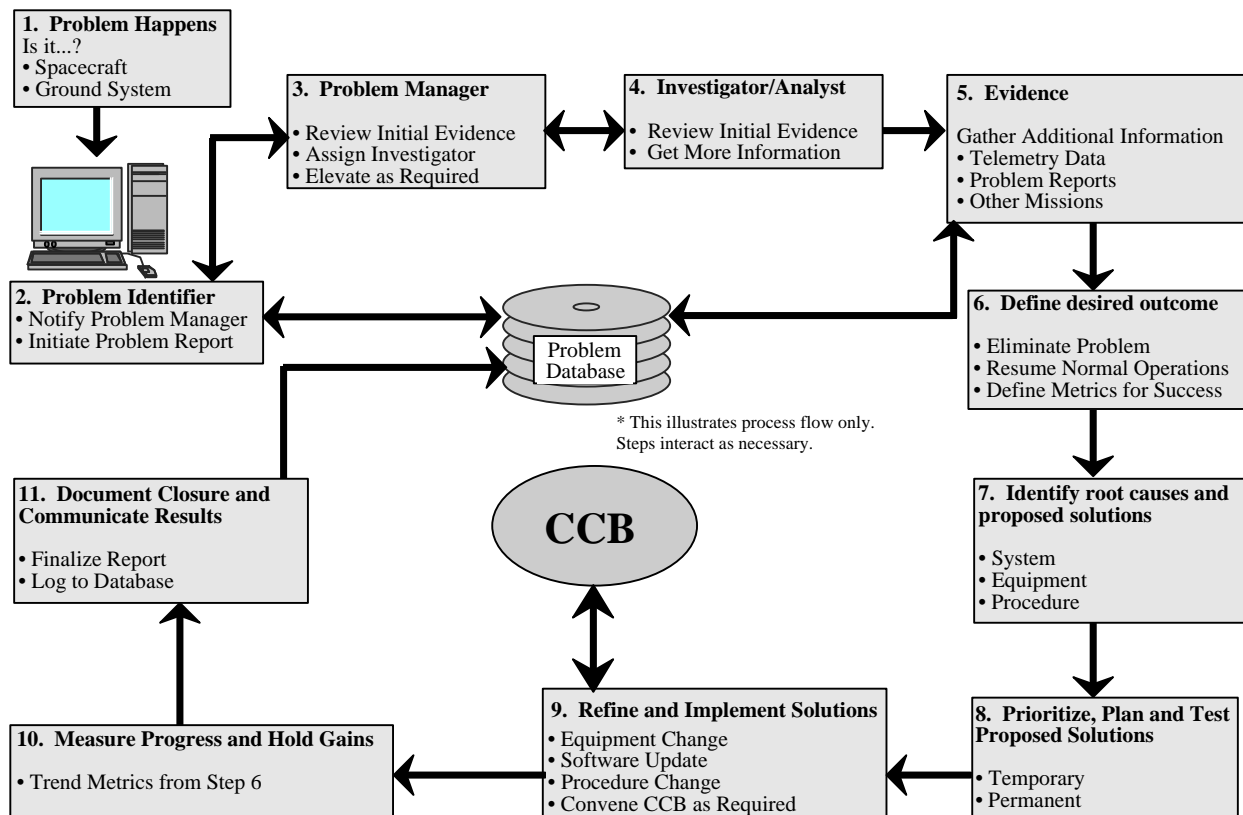


Figure 4-12. Steps Used in the Anomaly Resolution Process

4.6.4 Configuration Management

In the beginning of on-orbit Mission Operations, configuration management will be implemented as a natural evolution of the CM mechanisms used during the system development phases. The

objects controlled and the CM officers in authority will change appropriately, but the management philosophy will transition to operations with little change.

Configuration management for the operational EO-1 system includes the functions of configuration identification, configuration control, configuration status and accounting, and configuration audits.

Configuration identification will initially be accomplished at transition from development to operations by the functional and physical configuration audits of the operational EO-1 elements.

In keeping with the goal of simplifying and streamlining the configuration management process, the following philosophy applies:

- The CCB will constitute the sole configuration control entity for the EO-1 system. This ensures maximum control of system documentation. Approval of a controlled baseline or configuration change request (CCR) will be the sole responsibility of this CCB.
- Only documents that define a configuration affecting the form, fit, or function of the EO-1 system will compose the controlled baselines. These documents will be specified in an operational EO-1 Configuration Management Plan.
- Completed staff action, including technical coordination with all affected parties, will be accomplished prior to boarding a controlled baseline or CCR.

The CCB will include the Mission Manager and the Flight Operations Manager. The FOM will recommend to the Mission Manager and other key personnel, such as element managers, necessary to accomplish review and approval of technical baselines and CCRs.

The Mission Manager will also designate a Configuration Management Officer (CMO) to perform the administrative duties appropriate to the CCB. The CMO will be the individual primarily responsible for configuration status and accounting.

Configuration audits will be accomplished during the operational life cycle as directed by the Mission Manager. These will occur periodically, and whenever required by major system modifications.

4.7 Facilities

Elements providing housekeeping support are listed below along with their facility location during the on-orbit phase of the mission.

- MOC TBD
- NCC GSFC, building 14
- SN WSC, White Sands, NM
- AGS Fairbanks, AK
- SGS Svalbard, Norway (Spitzbergen)
- WOTS Wallops Island, VA
- FDF GSFC, building 32 and 28
- WOTIS Wallops Island, VA

Figure 4-13 shows the MOC facility. Note: The management offices contained within the MOC are not shown.

Facility management for the MOC will be provided by the GSFC Building 32 Facility Operations Manager (FOM). Procedures for facility operations (temperature control, etc.) and contingency plans (fire response procedures, etc.) will be made available to the FOT. Arrangements for general facility maintenance and janitorial services will also be provided.

MOC facility operations will also be generated by the FOT. In addition to the contingency plans mentioned in 6.3, there will be standard operating procedures that deal with facility issues (Preventative maintenance on MOC hardware, for example).

TBD

Figure 4-11. EO-1 MOC Facility

4.8 Logistics

Procedures for obtaining necessary logistical supplies for the support of spacecraft and MOC operations will be generated.

Section 5. Pre-Launch, Launch, and Contingency Operations

5.1 Pre-Launch Planning, Testing, and Training

The Pre-launch Planning and Testing phase of the mission extends from the initial deliveries of ground system software, through spacecraft I&T activities, to launch. Several types of tests are run during integration of the system. Individual elements will test and validate their hardware and software prior to accepting the systems as operational. These tests will be performed for each software release. These tests will be described in the element test and acceptance plans. In addition to these tests, cross-element tests will be performed to validate the integration of the system. The document that describes pre-launch tests is the EO-1 Ground System Integration and Test Plan. Functions such as data and command flow, file transfers, data processing, RF compatibility, operational procedures, etc. will be exercised during these tests. The Mission Readiness Manager (MRM) is responsible for certifying that requirements in the Detailed Mission Requirements (DMR) Document have been met. In addition, data flows and system tests will be run to ensure proper system interaction. These tests include end to end system tests and may involve monitoring, or participating in the spacecraft integration and testing activities.

The various ground system elements that will support testing and simulations include: NASA Communications (Nascom), Automated Wallops Orbital Tracking Station (Prime support) or other stations for backup support, EO-1 Science Data Center at GSFC, and the Land Processes Distributed Active Archive Center (LP DAAC) at Sioux Falls, South Dakota. These elements will be required to support pre-launch testing, data flows, element interface testing, and simulations in accordance with the following activity schedule.

Launch Minus	Test Conducted
18 months	Second FOT person joins project in preparation for I&T.
12 months	RF compatibility tests.
10 months	EO-1 to ground system compatibility testing. EO-1 command and telemetry data flow tests.
8 months	Third FOT person joins team in preparation for launch.
6 months	All elements of ground systems ready for interface testing, data flows, and simulations.
5 months	Project operations testing.
1 month	Launch readiness testing.

Figure 5-1. Testing Timeline

Mission readiness testing and simulations will be conducted in accordance with the EO-1 Ground System Integration and Test (I&T) Plan. Flight mission readiness testing will begin at approximately L-12 months and continue until launch. The exact test schedules and simulation dates have not been developed; however, all support elements and interfaces between support

elements for the EO-1 launch will be tested to verify readiness. Additionally, the EO-1 spacecraft RF package will support testing for network compatibility with all support elements.

Data flow tests (beginning and ending with the experimenters and spacecraft subsystem managers) will be supported on request from the project at approximately L-6 months through launch for both the Launch and Early Orbit Phase and typical mission-day modes of operations.

Training for operations will begin when the second FOT person joins the team at Launch-18 months. A Training Plan covering the material needed to operate EO-1, where to locate this material, the methods used to train people to achieve this knowledge, and a test to certify that the person understands this knowledge will be developed. Training will consist of spacecraft I&T experience as well as training packages for operations not covered in I&T. This person will be an actual member of the I&T team and perform the duties associated with that position. The second FOT person will gain sufficient experience to train the next FOT person who will join the team at Launch-8 months. This third person will not receive the extensive training the second person will, but will be sufficiently trained to handle launch. Specialists from the EO-1 spacecraft development team will be asked to be on call for the duration of L&EO. 2 or 3 extra operations personnel will be hired to cover 24 hour operations while the check out and verification is being performed on the spacecraft.

5.2 *Launch and Early Orbit Operations*

The Launch and Early Orbit (L&EO) phase begins at launch and extends up to approximately 30 days. The emphasis during this phase is on EO-1 launch, spacecraft checkout, instrument power on and calibration. Activities included during this phase include the following:

- Launch vehicle launch and orbit insertion.
- EO-1 separation.
- Deployment of solar arrays and antenna boom.
- Successful tracking and orbit determination by NORAD.
- Initial EO-1 real time telemetry acquisition through the EO-1 Ground Segment (EGS).
- Initial orbit determination by the EGS.
- Complete functional checkout of spacecraft systems.
- ADCS sensor calibration.
- Safehold checkout.
- Insertion error correction burn, rendezvous burn, final orbit burn.
- Instrument turn on, calibration of instrument, and functional checkout.

The following overview describes the current spacecraft hardware and software launch configuration, discusses launch and separation events from the launch vehicle, and highlights expected operations during the L&EO operations phase.

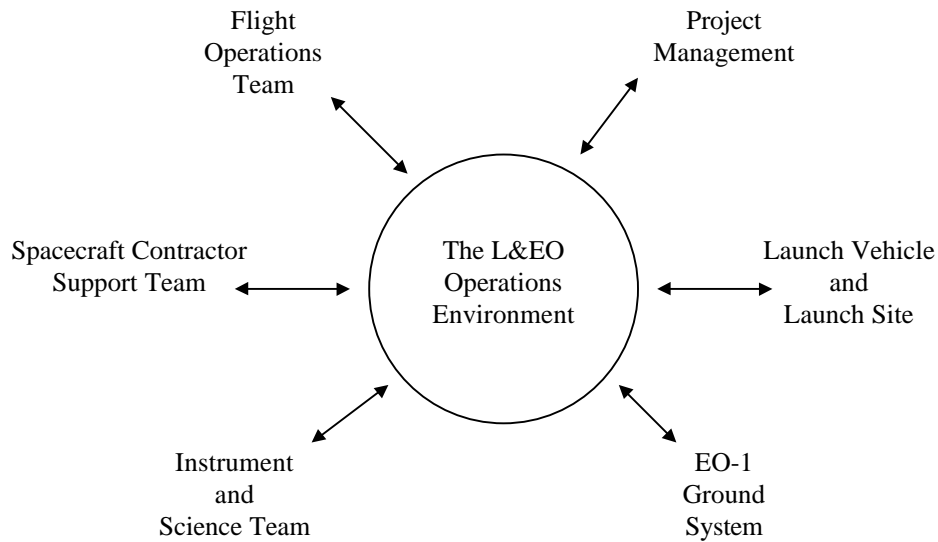


Figure 5-2. The L&EO Operations Environment

L&EO operations will require the intense coordination of many groups to deliver the EO-1 satellite to orbit and begin early orbit operations. The L&EO operations environment consists of those groups shown in Figure 5-2.

EO-1 L&EO operations will consist of the following operations phases:

- Launch Countdown Operations
- Launch and Ascent
- Deployment and Acquisition
- Acquisition and Maneuver
- Initialization
- Activation and Checkout

Minor launch operations plans and the launch operation timeline will be described and provided by the launch vehicle contractor. Figure 5-3 is a graphical representation of the initial acquisitions.

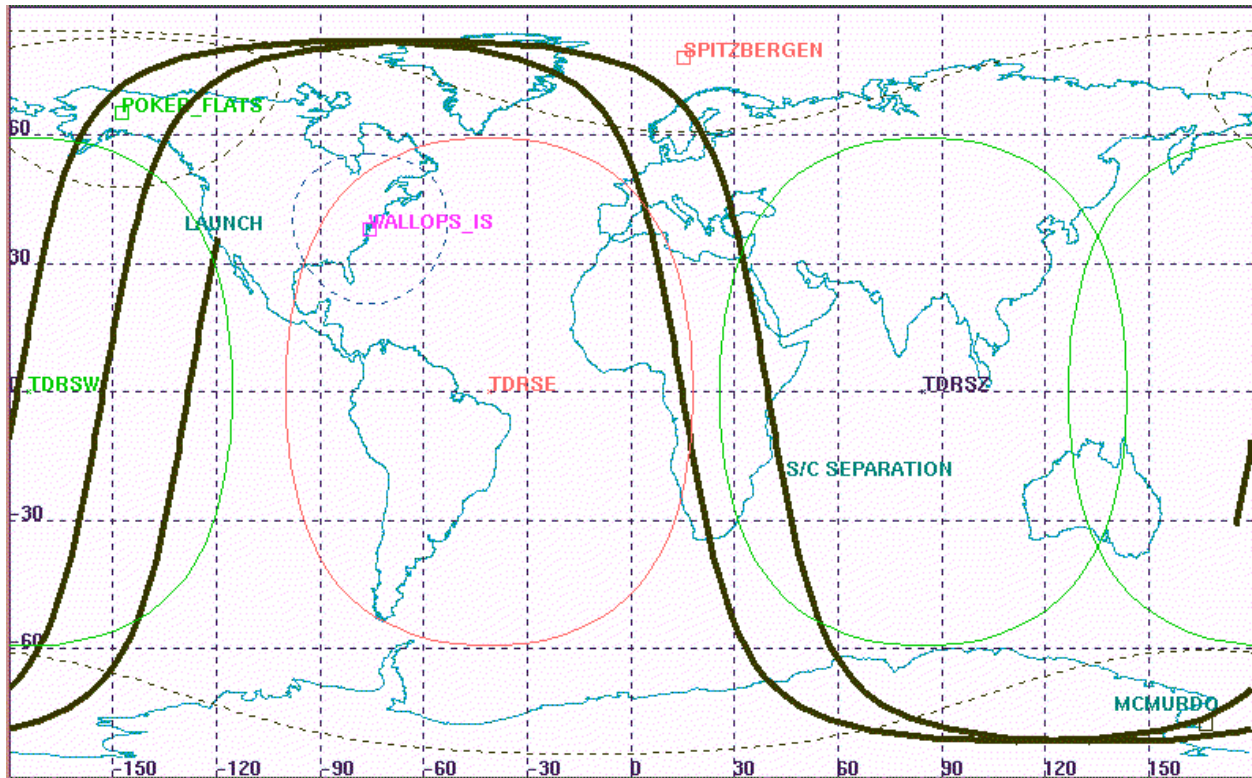


Figure 5-3. Initial Acquisitions

5.2.1 Launch Countdown Operations

Launch operations start at final checkout and configuration approximately L-18 hours before satellite ascent, separation, orientation, and the first support by the EGS at approximately L + 66 minutes over Spitzbergen.

Throughout most of the launch countdown sequence, the satellite is active with 14 Kbps telemetry data provided to the launch site Ground Support Equipment (GSE). This data will also be shipped to the MOC center at GSFC. An example preliminary launch countdown is illustrated in Figure 5-4 (this is an example modeled after the LLV1 launch vehicle, the Delta information is TBD).

Time	Duration	Major Event
-18 hours	4 hours	Electrical test complete Connect batteries Analyze data
-14 hours	30 minutes	Vehicle commit to arm Satellite commit to arm
-13.5 hours	7 hours	Vehicle arm begins
-6.5 hours	3 hours	Satellite arming
-3.5 hours	1 hour	Move mobile access structure to launch position
-130 minutes	5 minutes	Countdown begins, call to status, pre-launch checklist complete, verify resistance measurements of vehicle status through umbilical, status and alert checks

Time	Duration	Major Event
-125 minutes	10 minutes	Turn on external power supplies, verify voltages, apply external power
-115 minutes	15 minutes	RF band range checks on external power, open loop test on external power
-100 minutes	30 minutes	Load mission software, bit by bit check, check sum verification
-70 minutes	60 minutes	Attitude sensor alignment and verification, final weather brief, range clear, sweep complete, radars are functional
-20 minutes	1 minute	Prepare C&DH sequencer
-20 minutes	Continuous	Begin SRR health and safety record at 12 Kbps
-10 minutes	5 minutes	Check battery voltage, verify relative value of external power supply transfer to internal power, RF band checks on internal power, open loop test on internal power, range launch countdown switch enable
- 5 minutes	4.5 minutes	Launch vehicle countdown switch enable EO-1 on internal power “Go” for launch decision
-30 seconds	.5 seconds	Auto sequence begins
-29.5 seconds	19.5 seconds	Ignition arm relay
-.9 seconds	.9 seconds	Ignition arm and fire
0		Launch of EO-1 satellite

Figure 5-4. Preliminary Launch Countdown

5.2.2 Launch and Ascent

Ascent operations for EO-1 will involve the receipt of data from the launch vehicle (via the launch vehicle ground support system) to monitor launch vehicle performance during the ascent phase. Figure 5-5 shows the major events during this phase. This is preliminary and will be updated when Delta information is received.

Time	Duration	Major Event
0 minutes	2 minutes	First stage burn to separation
0 minutes	20 minutes	ADCS in Launch mode
0 minutes	2 minutes	Umbilicals pulled on the power subsystem
2 minutes	5 minutes	Second stage burn
5 minutes	1 minute	Second stage separation
10 minutes	TBD minutes	Transmitter on
12 minutes	TBD minutes	AOS TDW
18 minutes	Continuous	Rate null / BDOT control / Magfield rates - ADCS subsystem
42 minutes	TBD minutes	Coarse sun + Magnetic rate + IRU rate compare
42 minutes	1 minute	RLG turnon
42 minutes	3 minutes	Solar Array deploy rate verification
43 minutes	Continuous	Coarse sun (night rate damp) + Gyro rate
46 minutes	2 minutes	Solar array deployment
48 minutes	3 minutes	Solar array rotation to index
66 minutes	10 minutes	First Acquisition with Spitzbergen

Figure 5-5. Launch and Ascent Events

5.2.3 Deployment and Acquisition

EO-1 separation activities will be launch vehicle and satellite controlled through timer and / or stored command activities. The separation activities begin with spacecraft separation from the launch vehicle third stage and end with the spacecraft in a stable sun pointed attitude under autonomous control. Spacecraft operations in this phase are all autonomous including verification and retry of solar array deployment. As such, all separation activities do not require ground intervention.

The EGS will receive the separation state vector from the launch support service (service TBD) within 15 minutes of separation. After the initial acquisition, the initial state of health of the spacecraft will be known.

Key deployment activities include:

- Solar array deployment.
- Earth acquisition by the spacecraft.
- Transition to science mode.

The acquisition phase includes the activities associated with acquiring a safe, healthy, free-flying satellite in orbit. A safe spacecraft is dependent upon:

- Survival of the launch environment.
- Attitude acquisition on the sun (power positive mode).
- Orbit determination.
- RF acquisition with the ground site.

Key acquisition activities include:

- Spacecraft enables maneuver mode control (only if necessary for contingency operations).
- Spacecraft preparation for first acquisition with ground station.
- EGS receipt of spacecraft state vector.
- EGS RF acquisition of the spacecraft.

5.2.4 Early Orbit Checkout and Instrument Activation

Initialization after attitude and RF acquisition will include the initialization of key satellite subsystem components necessary for safe orbital operations.

Initialization will involve:

- Flushing the Mongoose V buffer.
- Loading a stored command load
- Initial clock synchronization activities.
- Initiate short cycle recorder operations (short record and dump operations to return engineering data to the ground as quickly as possible for anomaly investigations and overall subsystem performance).
- Validate the general performance of all subsystems against expected performance values and reconfigure subsystems as needed for contingencies discovered.

After the above operations have been accomplished, the satellite will be in a safe mode under normal orbital cycling conditions. All basic subsystems will have been validated, and the basic store and dump mode of operations will have been established.

At this point, key activities will include:

- Up-linking stored commands.
- Performing any necessary orbit adjust maneuvers (excluding the formation flying operations, which will be accomplished on board the spacecraft).
- Checking out the formation flying, GPS attitude and orbit determination, and star tracker system operation.

Checkout operations involve the systematic review of subsystem performance, and the commanding of subsystem modes and configurations deemed necessary for conduct of the mission so as to assure operability and determine performance levels. Checkout activities will occur for a set amount of time each day, centered around real time contact times with available ground stations. Time for contingencies and re-planning will be set aside each day.

Checkout activities include:

- The checkout of the items in the following list (in the set order, followed as closely as possible, banning contingencies):
 1. Critical spacecraft bus capabilities.
 2. Prime spacecraft bus capabilities.
 3. Backup spacecraft bus capabilities (TBC).
 4. Prime instrument capabilities.
 5. Backup instrument capabilities (TBC).
- Activation and checkout of components not previously activated.
- Power system checkout.
- RF and C&DH checkout.
- Full WARP playback.
- Spacecraft outgassing.
- Activation and checkout of payloads.

Once the performance of the satellite is determined, a review of the ground system models, constraints, hazards, limit checks, and so forth will be made with updates implemented as needed. A period of time anywhere from a month to three months should be set aside to perform all of the activities in Section 5.2. Normal operations can then commence.

Figure 5-6 shows a timeline of spacecraft events from the first acquisition through the end of checkout. FOT operations will be accomplished around these activities.

Time	Duration	Major Event
66 minutes	10 minutes	First Acquisition with Spitzbergen
68 minutes	8 minutes	250 Kbps playback of recorder
Day 1	TBD	GPS turnon Spitzbergen passes
Day 2	Continuous	Local vertical, earth pointing attitude
Day 2	TBD	Magnetics + Star Tracker control Kalman Filter checkout Safehold checkout

Time	Duration	Major Event
		Lightweight solar flexible array deployment Spitzbergen passes
Day 3	TBD	Slew mode checkout (gyro calibrations) Thruster checkout First burn Instrument turnon Spitzbergen passes
Day 4	TBD	IRU/CSS calibration Tam/MTB calibration Maneuver checkout Spitzbergen passes
Day 5	TBD	Calibration burn Second burn Spitzbergen passes
Day 6	TBD	Calibration parameters upload Spitzbergen passes
Day 7	TBD	Calibration burn Third burn Spitzbergen passes
Day 8	TBD	Maneuver Delta insertion error correction Spitzbergen passes
Week 2	TBD	Tam/MTB calibration Start rendezvous burn Spitzbergen passes
Week 3	Continuous	Tam/MTB calibration
Week 3	TBD	Spitzbergen passes
Week 4	Continuous	Tam/MTB calibration
Week 4	TBD	Final orbit burn Transition to normal operations Spitzbergen passes

Figure 5-6. Early Orbit Checkout and Instrument Activation Events

5.2.4.1 Roles and Responsibilities

A variety of personnel will be involved with the EO-1 launch. Figure 5-7 shows each organization and their particular involvement. This list does not include everyone who may be involved, but it does list those who must be involved.

Organization	Involvement
FOT	Monitor EO-1 Health and Safety during all phases. Control and conduct planned sequence of activities. Conduct 24 hour operations for the duration of L&EO.
Ground System Project Manager	Assist in FOT activities. Point of contact with the Project.
Ground System Developers	Assist in ground system software problem resolution. Be on call for support.
Spacecraft Developers	Assist in spacecraft problem resolution.

Organization	Involvement
	Monitor spacecraft performance. Provide calibration information to the FOT for uplink.
Mission Science Team	Conduct instrument initialization and checkout. Analyze instrument data for error detection and correction. Perform instrument calibration.
Flight Dynamics Personnel	Formation flying support, FDS support.

Figure 5-7. L&EO Roles and Responsibilities

5.2.4.2 Launch Operations and Hand Over

Launch operations are conducted by the launch service contractors. The spacecraft contractor and the ground system personnel will provide on site support during the launch phase. The EGS shall receive telemetry from the launch service contractors to monitor launch. After the EGS receives the separation state vector from the launch service, it will take control of operations.

5.3 Contingency Operations

Contingencies fall into two categories; ground system problems and spacecraft problems. Spacecraft anomalies are usually more urgent than communication errors because an anomaly has actually occurred onboard the satellite. Communication anomalies usually cause a loss of contact with the spacecraft, but rarely threaten its safety directly.

Spacecraft contingency operations will be discussed in great detail in documentation provided by the spacecraft contractor. These documents provide the best information on spacecraft operations and fault detection and procedures. Ground system problems will be discussed in the documentation provided with each subsystem as it is designed and handed over to the Project.

The information presented in this document describes the EGS failure detection and recovery procedures. General contingency procedures are discussed, followed by some specific examples of common contingencies which have occurred on other spacecraft and ground systems.

Contingency Operations may be needed during real-time or off-line operations. Any operation done in response to a non-nominal event or situation will be considered a contingency operation. Given this broad definition it will be impossible to identify all of the contingency procedures and operations that may be needed during the life of the mission. However, prior to launch, each element will have in place a set of agreed upon contingency operations for operators to follow during given anomalous situations. In those situations where no specific procedure is identified, the operators will rely on experience and higher level policies and procedures to choose a course of action.

For the FOT, the main goal of any contingency operation is to ensure the health and safety of the spacecraft. This may result in putting the spacecraft into a thermal and power steady mode with no ALI activity, or it may mean the resumption of normal data gathering operations. The reaction and result is wholly dependent on the anomalous condition being responded to. Certain anomalies

will require real-time responses while others may be worked on in an off-line environment as long as no immediate danger to the spacecraft is present.

Contingency operations for real-time operations will be aimed at minimizing the loss of data being dumped to the ground. Contingency plans for anomalies or problems that occur off-line will be aimed at restoring the system to a state where a normal flow of data may be achieved and collection of data from the spacecraft is not effected.

Prior to launch there will be a program-wide system and/or policy used for the response to, and tracking of, anomalies and problems. The system will coordinate and control the updating of all contingency procedures as necessary and provide a system-wide archive of all ground and spacecraft anomalies.

To obtain details concerning the payload contingency operations, see section 6.7 of this document.

5.3.1 Basic Contingency Procedures

The FOT will be equipped with numerous tools to recognize, and in some cases resolve, an anomalous situation in real-time. A list of these tools is given below:

Tool	Spacecraft or Communications Anomaly
RTS limit checking capabilities	Spacecraft
Asist	Spacecraft and Communications
Configuration monitors	Spacecraft and Communications
WOTIS interface	Communications
NCC OPMs and ODMs	Communications
NCC TNC	Communications
Contingency Operations Database	Spacecraft and Communications
FOT experience and training	Spacecraft and Communications

Figure 5-8. Anomaly Resolution Tools

There will be a database maintained and updated in the MOC that consists of fault isolation decision trees to aid in the diagnosis of anomalous situations. The database will contain contingency operations for specific situations including any procedures, commands, or command procs that need to be executed by the FOT in real-time.

5.3.1.1 Detection

Spacecraft contingencies are detected by either direct observation of real time data, determination during playback of recorded real time data, or extrapolation of problems during trending of recorder playback data.

Real time detection will be assisted by:

- MCC limit checking capabilities.
- Real time procedures written to check the spacecraft and ground system subsystem status at various times during the pass.
- Expert systems.
- Direct observation of telemetry in the form of pages or other graphic media by the FOT.

Off line detection will be accomplished using:

- Trending of stored spacecraft and instrument health and safety data.
- Analysis the stored data using specially designed software.

5.3.1.2 Response

The response a contingency merits depends upon it's severity, and whether or not it was thought of beforehand. Some contingencies are non recoverable, such as a piece of the satellite falling off or other severe problems, but most can be dealt with with work arounds. Work arounds are discovered with much cooperation from the system designers and builders. When a contingency is discovered, the following actions are taken:

- If the problem is satellite life threatening, emergency meetings or measures are conducted. The satellite has onboard EDAC and safehold, so if a life threatening situation develops, the satellite will usually be in safehold when the problem is found.
- If the problem is not life threatening, meetings will be conducted to resolve the problem or decide upon a work around. The mission manager will conduct these meetings.
- A course of action will be decided upon, which will usually involve loading prepared command loads, creating command loads (if the contingency has not been foreseen), sending up table loads to change on board characteristics, or conducting real time commanding.
- All the appropriate personnel will be notified of the problem and its resolution.

5.3.1.3 Planning Ahead

As launch approaches, much more information on contingencies will become available. Many STOL procedures will be written to deal with the contingencies that are the most likely to occur. The FOT will be trained to recognize the common contingencies and will know which STOL procedures should be used to deal with them. Contingencies that have occurred in the past on other missions will be accounted for, as well as problems that arise in I&T. The Flight Procedures Document, which will be written approximately one year before launch, will contain all the previously encountered contingencies along with their resolutions.

5.3.2 Spacecraft Contingencies

There are several degrees of anomalies that may occur on-board the spacecraft. The spacecraft is designed with an Error Detection and Correction (EDAC) system that will check for certain anomalous conditions and react to them. Some of the actions that the spacecraft may take in response to an anomaly are as follows.

- Set a discrepancy flag.
- Switch to a redundant piece of equipment.

- Autonomously change component configuration.
- Shed Power load.
- Autonomously switch to one of the available safe modes.

In most instances, the FOT will first learn of an anomaly during, or replaying a real-time pass. The spacecraft contains a status buffer that will alert the FOT to any autonomous action that has been taken in response to a perceived onboard problem. Upon AOS, the MOC will check this buffer and react accordingly to any new flags or messages. Each of the possible actions that may be taken by the spacecraft and flagged in the status buffer will have associated with it a contingency procedure for the MOC to follow.

In most cases, an anomaly will occur while the satellite is out of view and it will be the responsibility of the MOC (during a real-time pass) to react to the situation. In some cases, the spacecraft will already be in some sort of safe-mode and the FOT will need to follow set procedures to investigate the cause of the safehold and safely bring the spacecraft back to an operational state.

When an anomalous condition is recognized, the MOC will react to it using established procedures whenever possible. When a procedure does not exist for a specific situation, the MOC will rely on contacting the FOT for their experience. A judgment will be made as to whether the condition may be allowed to continue or if immediate action will be needed. Also, additional supports from the ground sites may be requested.

5.3.2.1 Invalid Orbit Insertion

This can happen for a variety of reasons. Not everything can be prepared for or accounted for when determining the initial spacecraft orbit. After the initial spacecraft position is determined, the initial orbit can be determined. If it is not correct, a maneuver plan must be developed, approved, and implemented.

5.3.2.2 Safehold Recovery

The procedure for safehold recovery will be used the most frequently of all spacecraft contingency procedures. This contingency will be practiced several times during I&T.

5.3.2.3 Bit Flips

This can occur anywhere data is stored on board the spacecraft. Depending upon where the problem has occurred, recovery can be very easy or very difficult. A bit flip on board can usually be solved by reloading the software or data affected from the ground. Bit flips in the dumped data occur regularly, and it is because of this that error codes are put on the data.

5.3.3 Ground System Contingencies

Wallops/WOTIS personnel will assist in ground site problems (TBD). In addition, personnel at the ground sites may be in contact with the FOT during the pass and able to assist in any problems that arise.

Contingency operations for anomalous situations within the MOC will be generated and made available for the FOT. Situations such as failure of online or off-line equipment, loss of power within the control center, etc. will be detailed. Contingencies involving other facilities within the building will be handled by the Facility Operations Manager. See section 4.7 for operations of the facility.

5.3.3.1 Real Time Acquisition Failure

On EO-1, many of the real time passes will be held without the FOT being in the MOC. In this case, a problem with acquiring the data will either have to be handled by the ground station, or by whatever autonomous software is available at the station. Acquisition failure is a relatively common problem, so procedures will be written to deal with it.

5.3.3.2 Real Time Ground System Component Failure

When a FOT member is available, they can trouble shoot data problems by tracing the data flow and determining where the data has stopped. They then know where the problem has occurred and can try to solve the problem. Most of the time, problems with the ground system equipment are sorted out during the pre pass readiness test. This test is specifically for determining the readiness of the ground system to receive data.

Section 6. Image Assessment and Processing

6.1 Overview of Instrument Operations

Payload operations are those done in order to support collection, processing, archival, and distribution of EO-1 image products and facilitate the obtainment of the mission objectives. The LZP, SDC, LL and all ground stations support payload operations. These elements are responsible for successfully accomplishing the following tasks;

- Capture ALI and associated payload data.
- Process all captured data to level 0.
- Process data to Level 1R and 1G on user request and for calibration operations.
- Archive all level 0 data and associated data files.
- Generate and provide assessment and calibration information on ALI.
- Support the detection, investigation, and resolution of payload related anomalies.

A large portion of the payload operations will take place at the SDC. The FOT will schedule ALI operations from the MOC, and SDC will be the site of science data receipt, processing, archive, distribution and assessment. A high level view of payload operations is given in the following sections.

6.2 Overview of Instrument Data

The Advanced Land Imager (ALI) will collect data from five types of focal plane arrays and output them on five independent data packets.

- One array type which collects Multi-Spectral (MS) and Panchromatic (PAN) data that is output on the MS/PAN data port.
- Two Wedge Imaging Spectrometer (WIS) focal plane arrays, one covering the Visible/Near Infra-Red (VNIR) band, and the other covering the Short Wave Infra-Red (SWIR) band.
- Two Grating Imaging Spectrometer (GIS) focal plane arrays which also cover the VNIR and SWIR bands, respectively.

The EO-1 spacecraft will also have an Atmospheric Corrector instrument that will collect data for use in applying atmospheric corrections to the collected MS/PAN, WIS, and GIS data. Housekeeping telemetry, from both the ALI instrument and other spacecraft subsystems, will also be collected.

6.3 ALI Data Collection

The data output by the ALI MS/PAN, WIS VNIR, WIS SWIR, GIS VNIR, and GIS SWIR bands will be collected during Data Collection Events (DCE), during which one or more bands will be read. A DCE is defined as the time the Wideband Advanced Recorder Processor (WARP) is turned on to record, to the time the WARP recording is turned off. The ALI will remain on continuously. All of the focal plane arrays act as two dimensional push broom arrays so that

DCEs can vary in duration. Science DCEs will refer to data collected while looking at the Earth; these DCEs will be processed through radiometric, atmospheric, and geometric calibration processes, as described below in section 6.3, and used for the Landsat-7 scene comparisons. Calibration DCEs will refer to data collected on the Sun (with a diffuser in place), the moon, or an internal radiation source for radiometric calibration purposes. Note that all DCEs will contain dark current data collected with the ALI cover closed, which will also be used for radiometric calibration. Calibration DCEs and science DCE dark current will be used to update a calibration database.

The DCE data coming from the ALI will be read by the spacecraft's Wideband Advanced Recorder/Processor (WARP). The WARP will reorder pixels in the data stream as necessary to facilitate data compression. The WARP will then compress the DCE data, CCSDS packetize them, and store them in onboard memory for download over a ground contact at a later time. Housekeeping data collected during the DCE will also be stored in the WARP, as will Atmospheric corrector data. All data stored in the WARP will nominally be downloaded via the X-band link. Housekeeping will be collected in between DCEs, stored in the EO-1 spacecraft's command processor, and downloaded during contacts via the S-band link.

Nominally, during the two passes at Spitzbergen, the spacecraft will be scheduled to down-link 40 Gb of wideband real-time data per day on a 105 Mbps down-link. This 105 Mbps stream will be further separated into 52.5 Mbps In-phase (I) and Quadrature (Q) channels. Spacecraft contact periods are expected to range from 10 to 15 minutes each pass.

Real-time payload operations at Spitzbergen consist of capturing all down-linked wideband data on tape. This tape will be shipped to the MOC where it will be played back into the LZP.

A high level, chronological listing of activities and operations that will take place during a nominal real-time spacecraft contact at Spitzbergen is given below.

- Pre-Pass Operations
 - Verify operational readiness of the station hardware and software resources at least 15 minutes before the start of each EO-1 contact period.
- Pass Operations
 - At the EO-1 contact period start time, the station verifies the presence of an X-Band carrier and notifies the MOC. If the criteria are met, transition from Program Track to Autotrack mode. Confirm equipment lock status at expected Data Start time.
 - Monitor the status of all ground station subsystems for nominal indications.
 - Monitor wideband data receipt and record operations through the end of the contact period.
 - Verify LOS.
 - Verify the recording of all wideband data received for the whole contact period.
- Post Pass Operations

- Ground station displays and/or prints a Return Link Summary report for the processed contact period. The report is sent to the MOC (TBD).

6.4 Data Processing

Off-line operations at SDC consist of data processing and reprocessing, data archive, product distribution, customer interfacing, image assessment, planning and scheduling, and software and database management. These topics are discussed in the following sections.

6.4.1 Wideband Data Processing and Reprocessing (Level 0)

After receiving the wideband data, through off-line tape playback, LZIP begins the task of processing the captured data. The raw data is stored for 30 days so it is available for any necessary reprocessing. The LZIP generates Level 0, browse, and metadata files (collectively called the LZIP files), and make the LZIP files available for transfer to the SDC. Processing is required to take place within 16 hours of the raw data coming into the LZIP. LZIP may receive the equivalent of TBD ALI scenes per day of wideband data.

The LZIP also generates return link data quality and accounting information from the wideband data received on a post-pass basis. The LZIP provides Level 0 quality and accounting information as part of the metadata to the SDC for each of the sub-intervals processed.

After the appropriate data has been processed or generated, it is stored in the LZIP and a Data Availability Notice (DAN) is sent to the SDC. This notifies the SDC that there is data in the LZIP awaiting archive.

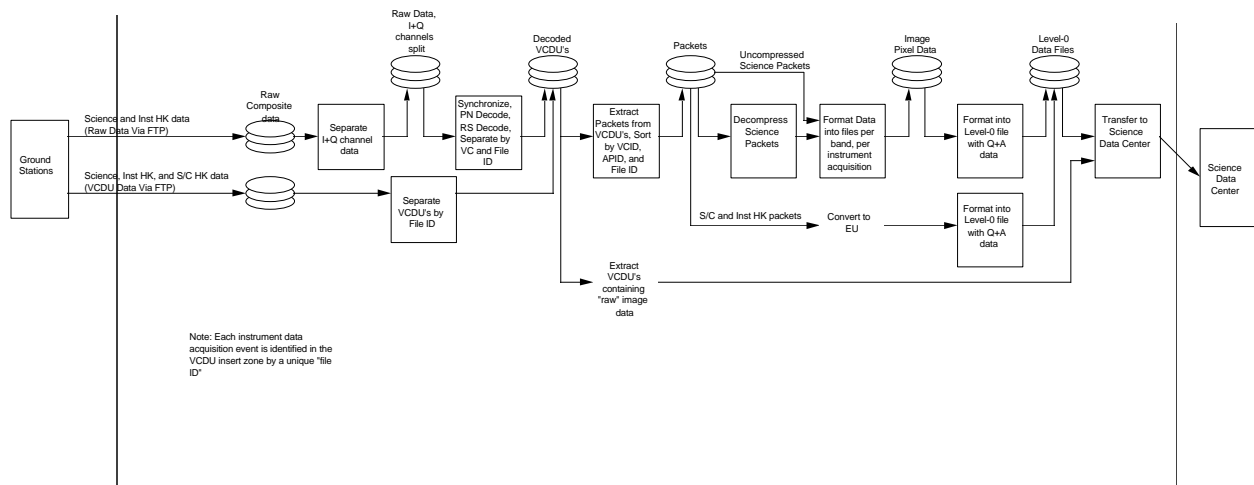


Figure 6-1. Level Zero Processing Block Diagram

6.5 Radiometric, Atmospheric, and Geometric Calibration of Data

The ALI and atmospheric corrector science data, along with spacecraft and ALI housekeeping telemetry data collected during the DCEs, will be downloaded from the EO-1 spacecraft WARP

via the X-band link during ground station contacts. Housekeeping data collected between DCEs and stored in the command processor will be downloaded over the S-band link, along with real time housekeeping data generated during the contact. All downloaded data will be temporarily stored on tape at the ground station and then sent to the MOC LZP at GSFC via an electronic link for level zero processing. At the LZP the packet contents will be extracted, decompressed, reformatted, and provided to the GSFC SDC. Standard level zero data quality information will accompany the data, and all raw data will be archived at the LZP.

The ALI data will then be processed through a system referred to as the “calibration pipeline”, which is depicted in Figure 6.2. MIT Lincoln Laboratories (MIT/LL), the instrument builder, will supply calibration data bases and software for their generation and maintenance to the GSFC SDC. The SDC will be responsible for the implementation of the software.

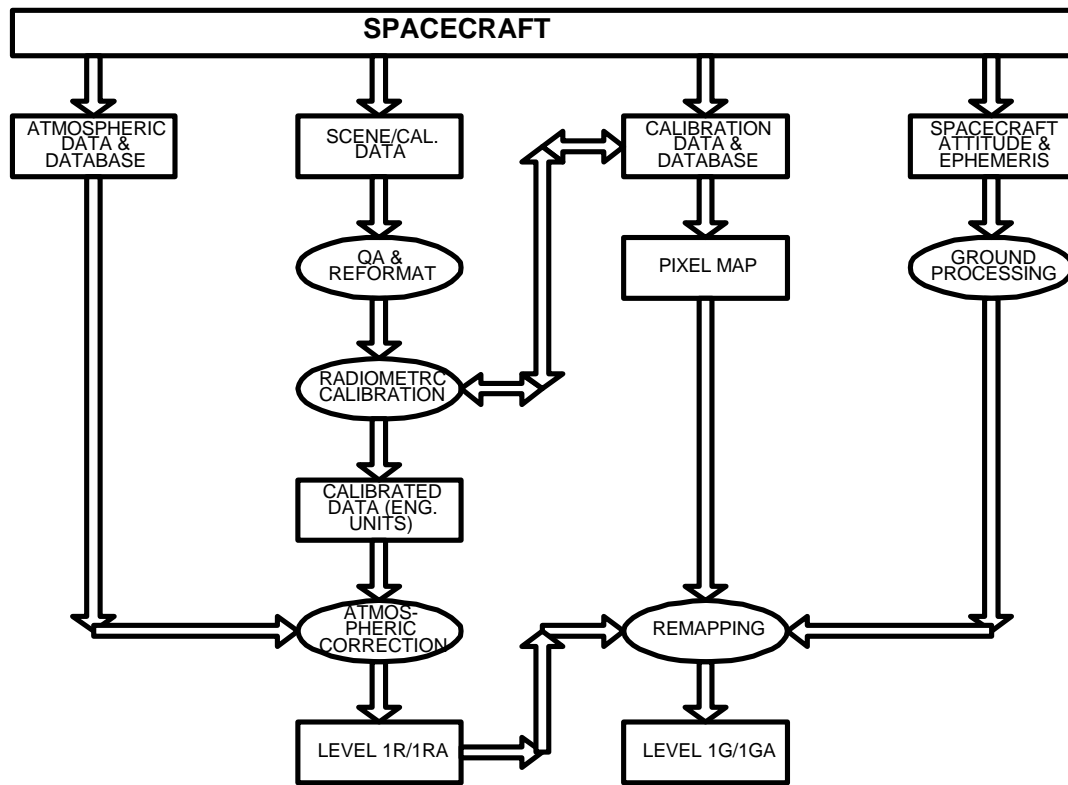


Figure 6-2. EO-1 Calibration Pipeline

The data calibration process is a joint GSFC - MIT/LL effort. The data will be adjusted and enhanced at the GSFC SDC by implementing the calibration data provided by MIT/LL. Radiometric calibration adjusts the data to variations in detector sensitivity and performance, and this information is provided to MIT/LL as an input into their calibration process. Atmospheric corrector information is then applied, and, finally, spacecraft attitude and ephemeris information is factored in. The data products resulting from radiometric, atmospheric, and geometric correction are termed level 1R, level 1RA, level 1G, and level 1GA, respectively. Some of the EO-1 science data will be processed further to compare them with similar Landsat 7 science data collected when EO-1 and Landsat 7 fly in formation.

6.6 *ALI Instrument Assessment and Calibration*

MIT/LL is responsible for assessing the spatial, spectral, and radiometric performance of the ALI, and will provide technical support for instrument assessment and calibration, as well as for resolving any contingency problems that arise with the ALI. They will request specific science and calibration DCEs to be run, specific types and amounts of data to be collected, and the uploading of specific commands or command sequences. These requests will be made as needed to support ALI performance assessment and contingency event resolution. MIT/LL will use the Level-0 and the (radiometric, atmospheric, and geometric) calibrated data, along with the spacecraft and ALI housekeeping data, to perform this function.

Conversion of the housekeeping data to engineering units will be accomplished through the workstation system used by MIT/LL, either at their facility or at GSFC. They will process all ALI housekeeping data with these workstations to perform long term trending of instrument health.

Appendix A: EO-1 System Interfaces

From	To	Product	Transport Mode	Comments
Ground Station	MOC	Equipment Status	T1 line	
Ground Station	Spacecraft	S-band Command Uplink	S-band RF @ 2 Kbps	2 times/day
Ground Station	MOC	S-band Telemetry (Real-time)	NASCOM T1 data line @ 32 Kbps	2 times/day
Ground Station	MOC	S-band Telemetry (from Mongoose V)	Same line specified in above, but at @ 4 Mbps rate	2 times/day
Ground Station	MOC	Status Information	TBD	2 times/day
Ground Station	MOC	Coordination During Pass	TBD	2 times/day
Ground Station	MOC	Command Echo Data	NASCOM T1 data line @ 32 Kbps	2 times/day
Ground Station	MOC	Command data for test link	T1 line	As required
Ground Station	MOC	Tracking Data	TBD	As required
WSG	MOC	Schedule Coordination	Internet / Voice Line	Once a week
Ground Station	MOC	X-band Telemetry	Mailed Tapes	Every contact
SDC	MOC	Schedule & Coordination Info	Internet / Voice Line	3 times a week
Ground Station	MOC	Clock & Time	TBD	Every contact
SDC	MOC	Status reports, anomaly resolution, coord.	Internet, Phone, Fax, Paper	As required
SDC	MOC	Sched requests, Prob Notification, Admin	Internet Connection	As required
SDC	MOC	Non-routine commanding	Internet Connection, Phone, Fax	As required

From	To	Product	Transport Mode	Comments
FDS	MCC	Planning Aids	Generated locally in MOC	Daily
FDS	MCC	Maneuver Planning, command data	Electronically	As required
FDS	MCC	Post-maneuver evaluation	Electronically	As required
FDS	MCC	Software	Manually, Electronically	Pre-launch
FDS	MCC	Activation Coordination	Electronically	L&EO
FDS	MCC	Miscellaneous Products	Electronically	As required
Vandenburg	Spacecraft	Power		
Vandenburg	GSE	Power, Communications		
Vandenburg	Delta			
Vandenburg	MOC	S-band Telemetry		
Vandenburg	MOC	Coordination		
Vandenburg	MOC	Schedule		
Vandenburg	MOC	Command data for test link		
Vandenburg	FDF	Launch Vehicle Telemetry Data		
Spacecraft	Delta	S-band Telemetry data	Umbilical	
Spacecraft	Ground Station	S-band Telemetry downlink (real time, housekeeping playback))	S-band RF @ 4000/250/32/2 Kilobits/sec	2 times/day
Spacecraft	Ground Station	S-band Telemetry downlink (playback and real time)	S-band RF @ 4 Mbps	Contingency Ops
Spacecraft	Ground Station	X-band Telemetry downlink	X-band RF 105 Mbps	2 times/day
TBS	Delta	Command data	Umbilical	
TBS	MOC	Telemetry		
TBS	LSIM	Command data for test link		pre-launch
TBS	VAFB	Communication, Coordination		pre-launch
Delta	AGE	Telemetry	Umbilical	pre-launch
Delta	Spacecraft	Command		L&EO
Delta	VAFB			L&EO
SDC	MOC	Calibration Parameter File	Internet Connection	
SDC	MOC	Calibration Scene Requests	Internet Connection	
SDC	MOC	Problem Reports	Internet Connection, Phone, fax	As required
SDC	MOC	Calibration Parameter Files	Nascom	
SDC	MOC	Reprocessing Requests	Nascom	As required
SDC	LL	Calibration Parameter Files	Nascom	
SDC	LL	Search Dialog	Nascom	Daily
SDC	LL	Product Requests	Nascom	Daily

From	To	Product	Transport Mode	Comments
SDC	Project	Status & Anomaly Resolution Coord.	Internet Connection	
MOC	Flight SW Facility (FSF)	Dump Image Files	Electronic	As required
MOC	FSF	Coordination	Voice	As required
MOC	Project	Status & Anomaly Resolution Coord.	Internet Connection, Phone, fax	As required
MOC	VAFB	Command Data		
MOC	VAFB	Coordination		
MOC	FDF	Event Schedules	Electronic	As required
MOC	FDF	Propulsion model updates	Electronic	As Needed
MOC	FDF	Telemetry	Electronic	Daily
MOC	FDF	Maneuver Planning	Electronic, Phone, fax	As required
MOC	FDF	Activation Coordination	Electronic, Phone, fax	As required
MOC	FDF	Post Maneuver Evaluation	Electronic, Phone, fax	As required
MOC	SDC	Schedule Requests	Internet Connection	1 time/week
MOC	Ground Station	Command Data (Single or Loads)	NASCOM Line @ 2 Kbps	2 times/day
MOC	Ground Station	Pass Coordination (Real-time) / Status	TBD	2 times/day
LZP	SDC	L0 Data	TBD	1 time/day
LZP	Project	Status reports & Anomaly resolution	Internet Connection, Phone, fax	As required
LZP	MCC	Data capture report (anomaly only)	Electronic	As required
LZP	MCC	Anomalous return link quality & accounting		As required
FSF	MOC	Image ID definition and Load image files	Internet	As required
FSF	MOC	Coordination	Internet, Phone	As required
Project	LL	Policy, guidelines, anomaly resol. coord	Internet, Phone, fax	As required
Project	LL	Mission information for guide server	Electronic	
Project	MOC	Special Requests	Internet and Phone	As required
Project	MOC	Long Term Plan and updates		As required
Project	MOC	Policy, guidelines, anomaly resol. coord	Internet and Phone	As required
Project	MOC	Flight Operations Management		Daily

Appendix B. EO-1 Acronym List

AC	Atmospheric Corrector
ADCS	Attitude Determination and Control System
AFSCN	Air Force Space Control Network
ALI	Advanced Land Imager
AOS	Acquisition Of Signal
AWOTS	Automated Wallops Orbital Tracking Station
BCR	Battery Charge Regulator
C&DH	Command and Data Handling
C&T	Commands and Telemetry
C-C	Carbon-Carbon
CCB	Configuration Control Board
CCR	Configuration Change Request
CCSDS	Consultative Committee for Space Data Standards
CDR	Critical Design Review
CEI	Contract End Item
CIS	Copper Iridium Diselenide
CM	Configuration Management
CMD	Command
CMO	Configuration Management Officer
COM	Communication
CTE	Coefficient of Thermal Expansion
DCE	Data Collection Events
DMR	Detailed Mission Requirements
DPAF	Dual Payload Attachment Fitting
DRAM	Dynamic Random Access Memory
EDAC	Error Detection And Correction
EDC	EROS Data Center
EEPROM	Electrically Erasable Programmable Read-Only Memory
EGS	EO-1 Ground System
EIRP	Effective Isotropic Radiated Power
EO-1	Earth Orbiter 1
EOSDIS	Earth Observing System Data and Information System
EPS	Electrical Power Subsystem
EROS	Earth Resources Observation System
ETM+	Enhanced Thematic Mapper Plus
FDS	Flight Dynamics System
FODB	Fiber Optic Data Bus
FOM	Flight Operations Manager
FOT	Flight Operations Team
FOV	Field Of View
FPD	Flight Procedures Document
FSW	Flight SoftWare
Gbps	Giga Bits Per Second
GIS	Grating Imaging Spectrometer
GMT	Greenwich Mean Time
GPS	Global Positioning System
GRI	Ground Reference Image
GSE	Ground Support Equipment

GSFC	Goddard Space Flight Center
GSIT&T	Ground System Integration and Test
H/S	Health and Safety
HK	Housekeeping
HW	Hardware
I&T	Integration and Test
ICD	Interface Control Document
I _{sp}	Specific Impulse
Kbps	Kilo Bits Per Second
L&EO	Launch and Early Orbit
L/V	Launch Vehicle
LEISA	Linear Etalon Imaging Spectrometer Array
LL	Lincoln Lab
LOS	Loss Of Signal
LP DAAC	EOSDIS Land Processes Distributed Active Archive Center
LZP	Level Zero Processing
Mbps	Mega Bits Per Second
MCC	Mission Command and Control System
MIPS	Million Instructions Per Second
MIT	Massachusetts Institute of Technology
MOCD	Mission Operations Concept Document
MOC	Mission Operations Center
MOP	Mission Operations Plan
MOR	Mission Operations Review
MS	Multi-Spectral
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
Nascom	NASA Communications Division
NASDA	National Space Development Agency of Japan
NCC	Network Control Center
NMP	New Millennium Program
NORAD	NORTH american Aerospace Defense command
ODB	Operational DataBase
Ops	Operations
ORR/FOR	Operations Readiness Review/Flight Operations Review
PAN	Panchromatic
PDB	Project DataBase
PPF	Payload Processing Facility
PPT	Pulsed Plasma Thruster
PWR	Power
RAM	Random Access Memory
RCS	Reaction Control System
RF	Radio Frequency
ROM	Read Only Memory
RPM	Revolutions Per Minute
RSN	Remote Service Node
RT	Real Time
RTCS	Real Time Command Sequences
S/A	Solar Array
S/C	Spacecraft
SAC-C	Satelite de Aplicaciones Cientificas - C
SAI	Swales Aerospace, Incorporated
SC	Spacecraft Contractor
SCA	Sensor Chip Assemblies

SCC	Spacecraft Command Center
SDC	Science Data Center
SFDU	Standard Formatted Data Units
SGS	Svalbard, Norway (Spitzbergen)
SiC	Silicon Carbide
SN	Space Network
SOW	Statement Of Work
SSR	Solid State Recorder
STOL	Systems Test and Operations Language
SW	Software
SWG	Science Working Group
SWIR	Short Wave Infra-Red
TBC	To Be Confirmed
TBD	To Be Determined
TBS	To Be Supplied
TCP/IP	Transmission Control Program/Internet Protocol
TDRSS	Tracking and Data Relay Satellite Subsystem
TEC	Thermal Electric Cooler
TLM	Telemetry
TOTS	Transportable Orbital Tracking Station
UPS	User Planning System
USAF	United States Air Force
USGS	United States Geological Survey
V/T	Voltage/Temperature
VAFB	Vandenberg Air Force Base
VNIR	Visible/Near Infra-Red
WARP	Wideband Advanced Recorder Processor
WBS	Work Breakdown Schedule
WIS	Wedge Imaging Spectrometer
WOTIS	Wallops Orbital Tracking Information System
WR	Western Range
WSC	White Sands Complex